

APPENDIX A

Documentation of National Emission Estimation Methodologies
for Sources of Benzene, 1,3-Butadiene, and Formaldehyde

APPENDIX A

This appendix describes the recommended approach and key assumptions for each of the individual source categories. For each source category, the following items are covered:

- Pollutants for which emission estimates will be made;
- National activity level and/or emission estimates;
- Assumptions on process and controls, primarily as they relate to the original test data on which the emission factors are based;
- Recommended emission factors;
- Assumptions for major/area determinations; and
- Approach for spatial allocation.

Data and information sources that were used in preparing the above items are referenced in each section. Some of the more complicated estimation methodologies (e.g., for mobile sources, halogenated solvent cleaning, and structure fires) are described in more detail than the other methodologies.

In order to facilitate finding a specific source category description, the following is a list of the subsections in Appendix A, the corresponding source category discussed in that subsection, and the page number where it can be found.

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A.1 Onroad Mobile Sources

Results of recent work by the Office of Mobile Sources (OMS) on toxic emissions from onroad motor vehicles are presented in the 1993 report Motor Vehicle-Related Air Toxics Study (MVATS).¹ This report was prepared in response to Section 202(1)(1) of the 1990 Amended Clean Air Act, that directs EPA to complete a study of the need for and the feasibility of, controlling emissions of toxic air pollutants that are unregulated under the Act and are associated with motor vehicles and motor vehicle fuels.

The report presents composite emission factors for several toxic air pollutants derived from mass fraction speciation of total organic gas (TOG) emissions. TOG includes all hydrocarbons as well as aldehydes, alcohols and other oxygenated compounds.

Pollutants Addressed

- Benzene;
- 1,3-Butadiene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The Federal Highway Administration's (FHWA) estimated 1990 national activity level for onroad mobile sources is 2,147,501 million vehicle miles traveled (VMT).² This national activity level estimate was developed from the 1990 annual highway performance monitoring system (HPMS) reports from each State in the nation; the HPMS reports are the standardized format for reporting vehicle activity levels expressed as VMT to the FHWA. The VMT estimates account for travel by passenger cars, trucks, and motorcycles on all urban and rural roadways within each State. Table A.1-1 summarizes the 1990 VMT data.^{1,2}

Table A.1-1. Onroad Mobile Source Emission Estimates

State	Vehicle Miles Traveled ^a (millions)	Pollutants ^b		
		Benzene (tons/year)	1,3-Butadiene (tons/year)	Formaldehyde (tons/year)
Alabama	42,347	4,117	728	1,923
Alaska	3,979	387	68	181
Arizona	35,456	3,447	610	1,610
Arkansas	21,011	2,043	361	954
California	258,926	25,174	4,453	11,759
Colorado	27,178	2,642	467	1,234
Connecticut	26,303	2,557	452	1,195
Delaware	6,548	637	113	297
DC	3,407	331	59	155
Florida	109,997	10,694	1,892	4,996
Georgia	72,746	7,073	1,251	3,304
Hawaii	8,066	784	139	366
Idaho	9,849	958	169	447
Illinois	83,334	8,102	1,433	3,785
Indiana	53,697	5,221	923	2,439
Iowa	22,993	2,235	395	1,044
Kansas	22,849	2,221	393	1,038
Kentucky	33,639	3,271	578	1,528
Louisiana	37,667	3,662	648	1,711
Maine	11,871	1,154	204	539
Maryland	40,536	3,941	697	1,841
Massachusetts	46,130	4,485	793	2,095
Michigan	81,091	7,884	1,394	3,683
Minnesota	38,946	3,786	670	1,769
Mississippi	24,398	2,372	420	1,108
Missouri	50,883	4,947	875	2,311
Montana	8,332	810	143	378
Nebraska	13,958	1,357	240	634
Nevada	10,215	993	176	464
New Hampshire	9,844	957	169	447
New Jersey	58,923	5,729	1,013	2,676

Table A.1-1. (Continued)

State	Vehicle Miles Traveled ^a (millions)	Pollutants ^b		
		Benzene (tons/year)	1,3-Butadiene (tons/year)	Formaldehyde (tons/year)
New Mexico	16,148	1,570	278	733
New York	106,902	10,393	1,838	4,855
North Carolina	62,707	6,097	1,078	2,848
North Dakota	5,910	575	102	268
Ohio	86,972	8,456	1,496	3,950
Oklahoma	33,081	3,216	569	1,502
Oregon	26,738	2,600	460	1,214
Pennsylvania	85,708	8,333	1,474	3,892
Rhode Island	7,024	683	121	319
South Carolina	34,376	3,342	591	1,561
South Dakota	6,989	679	120	317
Tennessee	46,710	4,541	803	2,121
Texas	162,232	15,773	2,790	7,368
Utah	14,646	1,424	252	665
Vermont	5,838	568	100	265
Virginia	60,178	5,851	1,035	2,733
Washington	44,695	4,345	769	2,030
West Virginia	15,418	1,499	265	700
Wisconsin	44,277	4,305	761	2,011
Wyoming	5,833	567	100	265
Total	2,147,501	208,788	36,929	97,529

^aU.S. Highway Administration *Highway Statistics*, Washington D.C., 1990.

^bU.S. EPA/OMS Emissions Factors from MOBTOM, Ann Arbor, Michigan, 1993.

Assumptions on Process and Control Levels

A number of important assumptions were made in the development of these onroad emission factors. They include:

1. Increases in emissions due to vehicle deterioration with increased mileage is proportional to increases in TOG;

2. Toxics fractions remain constant with ambient temperature changes; and
3. The fractions are adequate to use for the excess hydrocarbons that come from malfunction and tampering/misfueling.

Emission Factors

The emission factors presented in the MVATS were developed using currently available emissions data in a modified version of the OMS's MOBILE4.1 emission model (designated MOBTIX) to estimate toxic emissions as a mass fraction of TOG emissions.⁴ All exhaust mass fractions were calculated on a vehicle-by-vehicle basis for six vehicle types: light-duty gasoline trucks with a gross vehicle weight less than 6,000 pounds, light-duty gasoline trucks, light-duty diesel vehicles, light-duty diesel trucks and heavy-duty diesel trucks.

OMS assumed that light-duty gas and diesel trucks have the same toxic mass fractions as light-duty gas vehicles and diesel vehicles, respectively. In developing mass fractions for light-duty gas vehicles and trucks, four different catalytic controls and two different fuel systems (carbureted or fuel injection) were considered. Mass fractions for heavy-duty gas vehicles were developed for carbureted fuel systems with either no emission controls or three-way catalyst. These toxic mass fractions were applied to TOG emission factors developed to calculate in-use emissions. These in-use emission factors take into consideration evaporative and exhaust emissions as well as the effects of vehicle age. The application of toxic mass fractions to TOG emission factors yield toxic emission factors. These toxic emission factors are aggregated for all vehicle types in Table A.1-2.³ OMS also performed multiple runs of the MOBTIX program to derive a pollutant-specific, composite emission factor that represented all vehicle classes, based on the percent of total VMT attributable to each vehicle class.

Table A.1-2. Mobile Toxic Emission Factors^a

Pollutant	Emission Factor (g/mile)
Benzene	0.0882
1,3-Butadiene	0.0156
Formaldehyde	0.0412

^aU.S. EPA/OMS, Ann Arbor MI, fax from Richard Cook to Joseph Mangino, Radian, August, 1992.

Major/Area Assumptions

The category of onroad mobile sources is a mobile source category.

Approach and Assumptions for Spatial Apportionment

The national emissions estimates for on-road mobile sources occurs in both rural and urban areas, with the greater concentration of vehicle activity typically associated with metropolitan areas. Using OMS emission factors and Federal Highway Administration's State VMT data, onroad emissions can be calculated for each State. These results are presented in Table A.1-1. There are no plans to spatially allocate the national emissions for this category since it is specifically excluded from requirements set forth in Section 112(c) of the Clean Air Act Amendments and therefore is not a high priority category for this inventory effort.

REFERENCES FOR ON-ROAD MOBILE SOURCES

1. U.S. EPA. 1993. Motor Vehicle-Related Air Toxicities Study (MATS). O.S., Ann Arbor, MI.
2. U.S. Federal Highway Administration's Highway Statistics. 1990. Washington, DC.
3. Personal communication between Richard Cook, U.S. EPA O.S., and Joseph Mangino, Radian, August, 1992.
4. U.S. EPA. 1992. Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, EPA-450/4-81-026d (revised). O.S., Ann Arbor, MI.

A.2 Nonroad Mobile Sources

Nonroad mobile sources include lawn and garden equipment, recreational vehicles and vessels, construction and industrial engines, agricultural and construction equipment, and airport service vehicles and equipment. These sources are usually uncontrolled and emit HAP's along with other pollutants as products of combustion.

In the past, States found it difficult to estimate emissions from these sources because the procedures were complicated and required data that were often not readily available. To facilitate the calculation of emissions from these sources, the EPA's Office of Mobile Sources (O.S.) developed the Nonroad Engine Vehicle Emission Study (NEVES) in 1991.¹ This study was originally developed to streamline the estimating procedures for SIP emission inventories for criteria pollutant (VOC, NO_x, and CO) emissions from all nonroad sources except aircraft, locomotive and commercial marine vessels. O.S. used activity data from the NEVES report and speciated VOC emissions to estimate selected toxic emissions.²

Pollutants Addressed

- Benzene;
- 1,3-Butadiene; and
- Formaldehyde.

National Activity Level/Emissions Estimates

The NEVES study provided annual activity data for 33 nonattainment areas in terms of utilization, horsepower hours, or fuel consumption, depending upon the type of equipment and the available emission factor.

Assumptions on Process and Control Levels

The NEVES report warns against relying too heavily on the toxic emission estimates due to the limited number of emission factors used in the report. Most of the HAP emission factors used in NEVES were derived from onroad vehicles rather than nonroad equipment.

Emission Factors

NEVES derives VOC emission factors for 79 equipment types, ranging from small equipment such as lawn mowers and chain saws, to large agricultural, industrial, and construction machinery. The equipment types were evaluated based on three engine designs: 2-stroke gasoline, 4-stroke gasoline, and diesel. Sources for the data include earlier EPA studies and information supplied by the engine manufacturers for tailpipe exhaust and crankcase emissions. When using test data on new engines, O.S. made adjustments to better represent in-use equipment emissions, taking into consideration evaporative emissions and increases in emissions due to engine deterioration associated with increased equipment age.

The toxic components of nonroad emissions were evaluated for broad equipment categories as the percent weight of the VOC emissions. NEVES provided estimates for total aldehydes. As noted in the Formaldehyde Locating and Estimating Document, it can be assumed that 70 percent of total aldehyde emissions from internal combustion is formaldehyde.³

Major/Area Assumptions

The category of nonroad mobile sources is a mobile source category.

Approach and Assumptions for Spatial Apportionment

The NEVES report provides national emission estimates in two inventories. Inventory A was derived from EPA research, while the B inventory was developed using data from industry and trade groups. In this survey, the national nonroad HAP estimates from both inventories were averaged (see Table A.2). Averaging of the A and B inventories is the preferred approach recommended in SIP guidance.

Table A.2. National Non-Road Emission Estimates^a

Inventory	U.S. Annual in-use Emissions (tons/year)		
	Benzene	1,3-Butadiene	Formaldehyde
A	109783	47816	
B	82205	35949	
Average	95994	41883	45719 ^b

^aSource: U.S.EPA/O.S., NEVES (1991)

^bFormaldehyde emissions were derived by speciating the averaged aldehyde emissions using a mass fraction of 0.70.

The NEVES report was based on the assumption that nonroad sources are correlated with population, that is, as population density increases, nonroad emissions increase. In this survey, the NEVES totals were spatially apportioned relative to the U.S. Department of Commerce population census.

REFERENCES FOR NONROAD MOBILE SOURCES

1. U.S. EPA. 1991. Non-road Engine Vehicle Emission Study (21A-2001), O.S., Ann Arbor, MI.
2. U.S. EPA. 1992. Procedures for Emission Inventory Preparation, Volume IV: Mobile Source, EPA-450/4-81-026d (revised). O.S., Ann Arbor, MI.
3. U.S. EPA. 1991. Locating and Estimating Emissions from Sources of Formaldehyde. EPA-450/4-91-012. Research Triangle Park, NC.

A.3 Nonroad Mobile, Aircraft

Toxicities are emitted from aircraft as a product of engine combustion. There are two main types of aircraft engines currently in use: turbojet and piston. A kerosene-like jet fuel is used in the jet engines, whereas aviation gasoline, which has a lower vapor pressure than automotive gasoline is used for piston engines. The aircraft fleet in the United States numbers about 198,000, including civilian and military aircraft. Most of the fleet is of the single- and twin-engine piston type and is used for general aviation. However, most of the fuel is consumed by commercial jets and military aircraft; thus, these types of aircraft contribute more to combustion emissions than do general aviation. Most commercial jets have two, three or four engines. Military aircraft range from single or dual jet engine fighters to multi-engined transport aircraft with turbojet or turboprop engines.

Despite the great diversity of aircraft types and engines, there are considerable data available to aid in calculating aircraft- and engine-specific hydrocarbon emissions, such as the database maintained by the Federal Aviation Administration (FAA), Office of Environment and Energy, FAA Aircraft Engine Emissions Database (FAEED).¹ This is the approach recommended in the Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources (Mobile Sources Guidance).² These hydrocarbon emission totals may be speciated to quantify the toxic components of aircraft emissions. Speciated toxic mass fractions are available in the EPA SPECIATE database.³

Pollutants Addressed

- Benzene;
- 1,3-Butadiene; and
- Formaldehyde.

National Activity Level/Emissions Estimates

To use current U.S. EPA guidance for estimating hydrocarbon emissions from aircraft as it appears in Mobile Sources Guidance, the mix of the national aircraft fleet must be characterized and the annual number of landings and take-offs cycles must be quantified. The source of such aircraft data is the 1994 FAA Air Traffic Activity Data.⁴

Assumptions on Process and Control Levels

Note that in this approach emissions were estimated for aircraft airport activity only; in-flight emissions cannot be calculated without considerable detailed data. This estimate also does not include any aircraft activity occurring at non-FAA control towered airports.

Emission Factors

The procedure used to estimate hydrocarbon emissions from aircraft, as recommended in Mobile Sources Guidance, is based on landing/take-off (LTO) cycles. The operating modes in an LTO cycle are: (1) approach, (2) taxi/idle in, (3) taxi/idle out, (4) take-off, and (5) climbout. Emission rates by engine type and operating mode are given in the FAEED. To use this procedure, the time in each of the operating modes must be determined or EPA defined defaults should be used. From this information, hydrocarbon emissions can be calculated for one LTO for each aircraft model in the national fleet. To determine total annual hydrocarbon emissions from any specific aircraft model, the emissions from a single LTO for the aircraft model would be multiplied by the number of annual LTOs for that aircraft model. To estimate the total national aircraft emissions, all annual aircraft model emissions would have to be totaled.

If detailed aircraft information is unavailable, hydrocarbon emission indices for representative fleet mixes are provided in the Mobile Sources Guidance. The hydrocarbon emission indices are: for general aviation, 0.394 pounds per LTO (0.179 kg per LTO) and for air taxis, 1.234 pounds per LTO (0.560 kg per LTO). The total hydrocarbon emissions presented in Table A.3-1 were calculated using this approach.

Table A.3-1. Aircraft Hydrocarbon Emission Estimates

Aircraft Type	National LTOs^a	Hydrocarbon Emission Indices^b	Total Hydrocarbon Emissions (tons)
General Aviation	19,584,898	0.394	3,858
Air Taxis	4,418,836	1.234	2,726

^aLTOs are for 1990 and are from Table 1.7 in the FAA Air Traffic Activity (1993)

^bHC Emission Indices are from US EPA/OAQPS Emission Estimating Procedures Volume IV: Mobile Sources (1992).

The toxic component of the hydrocarbon total can be estimated by using the mass fractions from SPECIATE (see Table A.3-2). Since air taxis have larger prop engines and more of the fleet is equipped with jet engines

than the general aviation fleet, it is expected that the toxic mass fractions are somewhat different for these two aircraft categories. Considering that commercial aircraft are usually equipped with jets and general aviation aircraft are equipped with turboprops, to approximate toxic mass fractions for air taxis, the commercial and general aviation mass fractions were averaged.

Table A.3-2. Speciated Aircraft Hydrocarbon Estimates

Pollutant	Percent Weight of Hydrocarbon Emissions		
	Commercial Aircraft ^a	General Aviation ^a	Air Taxis ^b
Benzene	1.94	1.79	1.87
1,3-Butadiene	1.80	1.57	1.69
Formaldehyde	15.01	14.14	14.58

^aUS EPA SPECIATE Database.

^bValues for air taxis were derived by averaging commercial and general aviation rules.

As there are no hydrocarbon emission indices for commercial or military aircraft, national emissions from these aircraft categories cannot be estimated without considerable detailed activity and emission factor data (i.e., fleet mix and associated LTOs).

The appropriate toxic mass fractions were applied to the total national hydrocarbon emission values for general aviation and air taxis, yielding the national toxic emission estimates for these aircraft categories. These emission estimates are presented in Table A.3-3.

Major/Area Assumptions

The category of nonroad mobile, aircraft is a mobile source category.

Approach and Assumptions for Spatial Apportionment

It is assumed that general aviation and air taxi activity is correlated to population. Total national emissions were apportioned to each state relative to its populations.

Table A.3-3. Total National General Aviation and Air Taxi Emission Estimates

Aircraft Type	Hydrocarbon Totals (tons)	Benzene Mass Fraction (%)	Benzene Emission Totals (tons)	1,3-Butadiene Mass Fraction (%)	1,3-Butadiene Emission Totals (tons)	Formaldehyde Mass Fraction (%)	Formaldehyde Emission Totals (tons)
General Aviation	3,858	1.79	69	1.57	61	14.14	545
Air Taxis	2,726	1.87	51	1.69	46	14.58	397

REFERENCES FOR NONROAD MOBILE, AIRCRAFT

1. U.S. Federal Aviation Administration. FAA Aircraft Engine Emissions Database. Office of Environment and Energy, Washington, DC.
2. U.S. EPA. 1992. Procedure for Emission Inventory Preparation. Volume IV: Mobile Sources. EPA-450/4-81-026d (revised). O.S., Ann Arbor, MI
3. U.S. EPA. 1993. SPECIATE database, OAQPS, Research Triangle Park, NC.
4. U.S. Federal Aviation Administration. 1994. Air Traffic Activity Data, Washington, DC.

A.4 Industrial Wood Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The national activity level for industrial wood combustion for the base year 1990 is 90.6×10^6 tons oven dried wood burned.¹ The national activity level is reported by region (South, West, Northeast, Midwest) in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

Industrial wood-fired boilers are generally located at facilities which produce wood and bark waste products, including pulp and paper mills, lumber mills, furniture plants, and plywood mills. There are various boiler firing configurations used in industrial wood combustion. Three of the most common wood-fired boiler types in use are the Dutch oven, the fuel cell and the spreader stoker. The four most common PM emission control technologies in use are mechanical collectors (multicyclone), wet scrubbers, ESPs and fabric filters.² The emission factors presented are based on uncontrolled emissions from industrial wood-fired boilers burning bark waste.³

Emission Factors

Table A.4 lists the emission factors for each pollutant that were used to develop the national emissions estimate for industrial wood-fired boilers.³

Table A.4. Industrial Wood Combustion Emission Factors

Pollutant	Emission Factor	Units
Benzene	3.6×10^{-3}	lb/ton of wood burned
Formaldehyde	6.6×10^{-3}	lb/ton of wood burned

Major/Area Assumptions

The category of industrial wood-fired boilers is assumed to be a 80 percent major/20 percent area source, with 80 percent of wood-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. The higher percentage of major sources is due to the co-location of many of these boilers at pulp and paper facilities which are likely to be major sources.

Approach and Assumptions for Spatial Apportionment

Regional emission estimates were disaggregated to the county level using the county to Region ratio of the sum of the employment in SIC codes 261 (pulp mills) and 24 (lumber and wood products) from the 1990 U.S. Bureau of the Census database developed for this inventory.⁴ The majority of the industrial wood combustion occurs in these two industries. County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR INDUSTRIAL WOOD COMBUSTION

1. Energy Information Administration. 1991. Estimate of U.S. Biofuels Consumption 1990. Washington, DC. U.S. Department of Energy, Office of Coal, Nuclear, Electric, and Alternative Fuels. DOE/EIA-0548(90). p. 9.
2. U.S. EPA. October 1992. Emission Factor Documentation for AP-42 Section 1.6 - Wood Waste Combustion in Boilers. Draft Report. U.S. EPA, Technical Support Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC.
3. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
4. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.5 Industrial Coal Combustion

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for industrial coal combustion by coal type for the base year 1990 is:

- 114,815,000 tons of bituminous and lignite coal burned¹
- 390,000 tons of anthracite coal burned¹

The national activity level (combined coal types) is reported by State in the referenced EIA State energy consumption database. The benzene emission factor data represents boilers burning all three types of coal.

Assumptions on Process and Control Levels

The emission factor below represents a baghouse-controlled emission factor for a coal-fired industrial boiler.

Emission Factors

Table A.5 lists the emission factor that was used to develop the national emissions estimate for industrial coal combustion. The emission factor for benzene was obtained from CARB.²

Table A.5. Industrial Coal Combustion Emission Factor

Pollutant	Emission Factor	Units
Benzene	2.68×10^{-5}	lb/MMBtu coal burned

Major/Area Assumptions

The category of industrial coal-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of coal-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the

fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

Approach and Assumptions for Spatial Apportionment

The EIA coal consumption data for industrial sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC codes 20-39 (manufacturing industries) from the 1990 U.S. Bureau of the Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR INDUSTRIAL COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39-344.
2. CARB. Confidential Report No. ERC-70.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.6 Industrial Distillate Fuel Oil Combustion

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

The national activity level for industrial distillate oil-fired boilers for the base year 1990 is 39,000,000 barrels distillate fuel burned.¹ The national activity level is reported by State in the referenced EIA State energy consumption database. Emission factors were used to estimate emissions associated with the national and State level activity data.

Assumptions on Process and Control Levels

The emission factor below represents uncontrolled emissions from an industrial distillate oil-fired boiler, burning Grade 1 and 2 oil.

Emission Factors

Table A.6 lists the emission factor for formaldehyde that was used to develop the national emissions estimate for industrial distillate fuel oil combustion. The formaldehyde emission factor was obtained from AP-42.²

Table A.6. Industrial Distillate Fuel Oil Combustion Emission Factors

Pollutant	Emission Factor	Units
Formaldehyde	3.19×10^2	lb/E12 Btu fuel consumed

Major/Area Assumptions

The category of industrial distillate oil-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of distillate oil-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

Approach and Assumptions for Spatial Apportionment

The EIA distillate fuel oil consumption data for industrial sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC codes 20-39 (manufacturing industries) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR INDUSTRIAL DISTILLATE FUEL OIL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.7 Industrial Residual Fuel Oil Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The national activity level for industrial residual oil-fired boilers for the base year 1990 is 65,931,000 barrels residual fuel oil burned.¹ The national activity level is reported by State in the referenced EIA State energy consumption database. Emission factors were used to estimate emissions associated with the national and State level activity data.

Assumptions on Process and Control Levels

The emission factors presented below are for uncontrolled residual oil-fired industrial boilers burning Grade 6 oil.

Emission Factors

Table A.7 lists the emission factors for each pollutant that were used to develop the national emissions estimate for industrial residual fuel-fired boilers. The formaldehyde emission factor represents an average of two factors obtained from the FIRE database.² The emission factor for benzene was also obtained from the FIRE database.²

Table A.7. Industrial Residual Fuel Oil Combustion Emission Factors

Pollutant	Emission Factor	Units
Benzene	1.1×10^{-3}	lb/1000 gallons of residual fuel oil consumed
Formaldehyde	2.83×10^2	lb/E12 Btu of residual fuel oil consumed

Major/Area Assumptions

The category of industrial residual fuel-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of residual fuel-fired industrial boilers emitting more than 10 tons per year of a single

HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

Approach and Assumptions for Spatial Apportionment

The EIA residual fuel oil consumption data for industrial sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC codes 20-39 (manufacturing industries) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR INDUSTRIAL RESIDUAL FUEL OIL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.8 Industrial Natural Gas Combustion

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

The national activity level for industrial natural gas-fired boilers for the base year 1990 is $7,732 \times 10^9$ cubic feet natural gas burned.¹ The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The emission factor below represents an uncontrolled industrial natural gas-fired boiler.

Emission Factors

Table A.8 lists the emission factor for formaldehyde that was used to develop the national emissions estimate for industrial natural gas-fired boilers. The emission factor for formaldehyde was obtained from the formaldehyde L&E document.²

Table A.8. Industrial Natural Gas Combustion Emission Factors

Pollutant	Emission Factor	Units
Formaldehyde	2.22×10^{-4}	lb/MMBtu heat input

Major/Area Assumptions

The category of industrial natural gas-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of natural gas-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

Approach and Assumptions for Spatial Apportionment

The EIA natural gas consumption data for industrial sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC codes 20-39 (manufacturing industries) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR INDUSTRIAL NATURAL GAS COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. U.S. EPA. 1991. Locating and Estimating Air Emissions from Sources of Formaldehyde (Revised). EPA-450/4-91-012. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.9 Commercial/Institutional Wood Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The national activity level for commercial/institutional wood combustion for the base year 1990 is 1.7×10^6 short tons oven dried wood burned.¹ The national activity level is based on a 1986 Nonresidential Buildings Energy Consumption Survey conducted by EIA and reported in the referenced EIA State energy consumption database. Commercial sector wood consumption is not normally reported in that database because there are no accurate data sources to provide reliable estimates.

Assumptions on Process and Control Levels

Wood-fired boilers make up only 2 percent of the overall fuel consumption in the commercial/institutional sector; petroleum (distillate and residual fuel oil) and natural gas account for approximately 96 percent of the fuel use in this sector for external combustion.²

The emission factors presented below are based on emissions from an uncontrolled wood-fired commercial/institutional boiler.

Emission Factors

Table A.9 lists the emission factors for each pollutant that were used to develop the national emissions estimates for commercial/institutional wood-fired boilers.^{3,4}

**Table A.9. Commercial/Institutional Wood Combustion
 Emission Factors**

Pollutant	Emission Factor	Units
Benzene	7.2×10^{-3}	lb/ton dry wood burned
Formaldehyde	6.6×10^{-3}	lb/ton dry wood burned

Major/Area Assumptions

The category of commercial/institutional wood-fired boilers is assumed to be 20 percent major/80 percent area sources, with 20 percent of wood-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

National emission estimates for this category will be disaggregated to the county level using the county to nation ratio of employment in SIC codes 50-89 (trade and institutional services) from the 1990 U.S. Bureau of Census database developed for this inventory.⁵ County emissions will then be assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL WOOD COMBUSTION

1. Energy Information Administration. 1991. Estimate of U.S. Biofuels Consumption 1990. DOE/EIA-0548(90). U.S. Department of Energy, Office of Coal, Nuclear, Electric, and Alternative Fuels, Washington, DC. p. 6.
2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCA-TR-79-62-G. U.S. EPA, Industrial Environmental Research Laboratory, Research Triangle Park, NC. pp. 2 and 55.
3. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
4. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
5. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.10 Commercial/Institutional Coal Combustion

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for commercial/institutional coal combustion by coal type for the base year 1990 is:

- 3,575,000 tons bituminous and lignite coal burned;¹ and
- 493,000 tons anthracite coal burned.¹

The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The emission factor presented below is based on emissions from coal-fired, industrial boilers controlled with a baghouse.

Emission Factors

Table A.10 lists the emission factors for benzene that was used to develop national emissions estimates for commercial/institutional coal-fired boilers. The emission factor was obtained from CARB.²

Table A.10. Commercial/Institutional Coal Combustion Emission Factors

Pollutant	Emission Factor	Units
Benzene	2.68×10^{-5}	lb/MMBtu heat input

Major/Area Assumptions

The category of commercial/institutional coal combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all coal-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

The EIA coal consumption data for commercial/institutional sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of the employment in SIC codes 50-89 (trade and institutional services) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. CARB. Confidential Report No. ERC-70.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.11 Commercial/Institutional Distillate Fuel Oil Combustion

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

The national activity level for commercial/institutional distillate fuel oil combustion for the base year 1990 is 83,605,000 barrels distillate fuel burned.¹ The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The emission factor below is based on uncontrolled emissions from commercial/institutional distillate fuel-fired boilers.

Emission Factors

Table A.11 lists the emission factor for formaldehyde that was used to develop national emissions estimates for commercial/institutional distillate fuel-fired boilers. The emission factor for formaldehyde was obtained from AP-42.²

**Table A.11. Commercial/Institutional Distillate Fuel Oil
Combustion Emission Factors**

Pollutant	Emission Factor	Units
Formaldehyde	3.19×10^2	lb/E12 Btu fuel burned

Major/Area Assumptions

The category of commercial/institutional distillate fuel oil combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all distillate-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

The EIA distillate fuel oil consumption data for commercial/institutional sources were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC codes 50-89 (trade and institutional services) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL DISTILLATE FUEL OIL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.12 Commercial/Institutional Residual Fuel Oil Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The national activity level for commercial/institutional residual fuel oil combustion for the base year 1990 is 59,551,000 barrels residual fuel oil burned.¹ The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The emission factors presented below are for uncontrolled residual oil-fired boilers.

Emission Factors

Table A.12 lists the emission factors for each pollutant that were used to develop the national emissions estimates for commercial/institutional residual fuel oil-fired boilers. The emission factors for the pollutants that were used to develop the national emissions estimate for commercial/institutional residual fuel oil combustion were obtained from AP-42.²

**Table A.12. Commercial/Institutional Residual Fuel Oil
Combustion Emission Factors**

Pollutant	Emission Factor	Units
Benzene	1.1×10^{-3}	lb/1000 gallons fuel oil consumed
Formaldehyde	2.83×10^2	lb/E12 Btu fuel oil consumed

Major/Area Assumptions

The category of commercial/institutional residual fuel oil combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all residual oil-fired commercial/institutional facilities

emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

The EIA residual fuel oil consumption data for commercial/institutional sources are presented at a State level. Emission estimates will be initially developed at the State level. State level emission estimates will then be further disaggregated to the county level using the county to State ratio of employment in SIC codes 50-89 (trade and institutional services) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions will then be assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL RESIDUAL FUEL OIL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.
2. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.13 Electric Utility Coal Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The 1990 national emissions of the above pollutants from electric utility coal combustion were obtained from data developed for the draft version of EPA's Report to Congress on toxics from utility sources.¹ The emissions are shown in Table A.13.

**Table A.13. Electric Utility Coal Combustion
National Emission Estimates**

Pollutant	National Emissions (tons/yr)
Benzene	21
Formaldehyde	35

Assumptions on Process and Control Levels

The emission estimates were based on results of source tests from controlled and uncontrolled coal-fired (all coal types) utility boilers.¹

Emission Factors

Emission factors developed for the U.S. EPA for the draft Report to Congress on toxics from utility sources were used to develop national emission estimates.

Major/Area Assumptions

The category of electric utility coal combustion is assumed to be strictly a major source, with all coal-fired utility boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the consideration of other HAP emissions from these types of boilers, specifically hydrochloric acid (HCl) and hydrofluoric acid (HF). Documented emission factors for HCl and HF in the

EPA's PISCES Database,² a compilation of emissions test data on electric utility power plants, indicates that most coal-fired boilers in this sector would be major sources.

Approach and Assumptions for Spatial Apportionment

The EIA coal consumption data for electric utilities were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC code 4911 (electric services) from the 1990 U.S. Bureau of Census database developed for this inventory.³ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR ELECTRIC UTILITY COAL COMBUSTION

1. Jeffrey Cole, Research Triangle Institute. Memorandum to William Maxwell, U.S. EPA. Research Triangle Park, NC. January 19, 1995.
2. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, TX. pp. 2-3 - 2-10.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.14 Electric Utility Residual Fuel Oil Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The 1990 national emissions of the above pollutants from electric utility residual fuel oil combustion were obtained from data developed for the draft version of EPA's Report to Congress on toxics from utility sources.¹ The emissions are shown in Table A.14.

**Table A.14. Electric Utility Residual Fuel Oil
Combustion National Emission Estimates**

Pollutant	National Emissions (tons/yr)
Benzene	0.88
Formaldehyde	19

Assumptions on Process and Control Levels

The emission estimates were based on results of source tests from controlled and uncontrolled oil-fired utility boilers of various types (e.g., tangentially-fired and wall-fired).¹

Emission Factors

Emission factors developed for the U.S. EPA for the draft Report to Congress on toxics from utility sources were used to develop national emission estimates.

Major/Area Assumptions

The category of electric utility residual fuel oil combustion is assumed to be primarily a major source category. This assumption is based on the observation, drawn from DOE utility reporting data for 1990,² that most of the boilers in this sector are rated at a thermal input capacity of greater than 500 MMBtu/hour and that there is typically more than one boiler located

at a power plant facility. Considering the emission factors for benzene, nickel, and POM, which are documented³ for these types of boilers, and the observation just stated, an apportionment of 90 percent major sources and 10 percent area sources were made for this category. The 10 percent area sources represents a small fraction of boilers in this sector that have thermal input capacities less than 500 MMBtu/hour and which are not co-located at power plant facilities with other boilers.

Approach and Assumptions for Spatial Apportionment

The EIA residual fuel oil consumption data for electric utilities were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC code 4911 (electric services) from the 1990 U.S. Bureau of Census database developed for this inventory.⁴ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR ELECTRIC UTILITY RESIDUAL FUEL OIL COMBUSTION

1. Jeffrey Cole, Research Triangle Park Institute. Memorandum to William Maxwell, U.S. EPA. Research Triangle Park, NC. January 19, 1995.
2. U.S. Department of Energy. 1990. Form EIA-767 Reporting Data for 1990. Information Contained on File Labeled ("Int90out2.dat") on the EPA CHIEF Bulletin Board. Research Triangle Park, NC.
3. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, TX. p. 2-11.
4. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.15 Electric Utility Natural Gas Combustion

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

The 1990 national emissions of the above pollutants from electric utility natural gas combustion were obtained from data developed for the draft version of EPA's Report to Congress on toxics from utility sources.¹ The emissions are shown in Table A.15.

**Table A.15. Electric Utility Natural Gas
Combustion National Emission Estimates**

Pollutant	National Emissions (tons/yr)
Benzene	1.8
Formaldehyde	55

Assumptions on Process and Control Levels

The emission estimates were based on results of source tests from controlled and uncontrolled gas-fired utility boilers of various types (e.g., tangentially fired and wall-fired).¹

Emission Factors

Emission factors developed for the U.S. EPA for the draft Report to Congress on toxics from utility sources were used to develop national emission estimates.

Major/Area Assumptions

The category of electric utility natural gas-fired boilers is assumed to be primarily a major source category. This assumption is based on information contained in the DOE utility reporting database for 1990² and emission factors for HCl, nickel, and phosphorous contained in the PISCES Database.³ The DOE utility reporting database for 1990 indicates that most of the boilers in this sector have thermal input capacities greater than

500 MMBtu/hour. Using the emission factors from PISCES for HCl, nickel, and phosphorous, and a 500 MMBtu/hour thermal input capacity, most of these boilers would be classified as major sources considering their co-location with at least one other similar rated boiler at a power plant facility. For the purposes of this inventory, 90 percent of the boilers in this category will be classified as major sources, while 10 percent will be classified as area sources to reflect the small fraction of these boilers that have thermal input ratings under 500 MMBtu/hour and/or which are not co-located with another boiler at a power plant facility.

Approach and Assumptions for Spatial Apportionment

The EIA natural gas consumption data for electric utilities were available at a State level. Emission estimates were initially developed at the State level. State level emission estimates were then further disaggregated to the county level using the county to State ratio of employment in SIC code 4911 (electric services) from the 1990 U.S. Bureau of Census database developed for this inventory.⁴ County emissions were then assigned to one of three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR ELECTRIC UTILITY NATURAL GAS COMBUSTION

1. Jeffrey Cole, Research Triangle Park Institute. Memorandum to William Maxwell, U.S. EPA. Research Triangle Park, NC. January 19, 1995.
2. U.S. Department of Energy. 1990. Form EIA-767 Reporting Data for 1990. Information Contained on File Labeled "Int90ut2.dat") on the EPA CHIEF Bulletin Board. Research Triangle Park, NC.
3. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, TX. p. 2-13.
4. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.16 Residential Wood Combustion

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for residential wood consumption from EIA for the base year 1990 is 46 million tons of dry wood burned.¹ The national activity level is reported in regional segments for the U.S. The regional segments include: Northeast, South, Midwest, and West. Approximately 22.5 million households burned wood for either primary space heating (5 million households) or as a secondary source for aesthetic purposes (17.5 million households). The 5 million households where wood is burned for primary space heating used wood burning stoves as the principle heating appliance.

Assumptions on Process and Control Levels

Control of emissions from residential wood combustion depend mainly on the type of appliance in which the wood is being burned (i.e., a woodstove or a fireplace) and the practices of the homeowner operating the appliance. Woodstoves generally have higher emissions than fireplaces because they have lower burn rates; these lower burn rates result in higher heating efficiencies than fireplaces but also increases many of the organic emission rates due to incomplete combustion from the restriction of air flow into the appliance.

Since the implementation of regulatory requirements to control emissions from woodstoves,² catalytic and non-catalytic control devices have been installed on woodstoves to control their emissions. Catalytic controls use the same technology as catalytic converters on vehicles to reduce exhaust emissions. Non-catalytic controls include secondary combustion chambers and baffles.

The emission factor presented below is for emissions from an uncontrolled residential non-catalytic woodstove.

Emission Factors

Table A.16 lists the emission factor for benzene that was used in the inventory. The emission factor was obtained from the AP-42.³

Table A.16. Residential Wood Combustion Emission Factors

Pollutant	Emission Factor	Units
Benzene	1.938	lb/ton dry wood burned

Major/Area Assumptions

The category of residential wood consumption is assumed to be strictly an area source, with no single woodstove or fireplace emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

HAP emission estimates will first be developed at the regional level to correspond to the EIA regions (i.e., Northeast, South, Midwest, and West). The regional emission estimates will then be split up between rural and urban areas using the following percentages:

- 80 percent RURAL;
- 12 percent URBAN-2; and
- 8 percent URBAN-1.

These percentages were derived from the EIA's Estimates of U.S. Biofuels Consumption in 1990.⁴ If further disaggregation of the regional emission estimates is required for the final inventory report, the county to Region ratio of population from the 1990 U.S. Bureau of Census database developed for this inventory will be used to develop county level emissions.⁵

REFERENCES FOR RESIDENTIAL WOOD COMBUSTION

1. U.S. EPA. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, and Occurrence and Background Exposures. External Review Draft. Office of Health and Environmental Assessment, Washington, D.C. EPA-600/6-88-55b. June 1994.

2. U.S. EPA. February 26, 1988. Standards of Performance for New Stationary Sources: New Residential Wood Heaters. Federal Register, Volume 53, No. 38.
3. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
4. Energy Information Administration. October 1991. Estimates of U.S. Biofuels Consumption 1990. DOE/EIA-0548(90). pp. 9 - 12.
5. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.17 Hazardous Waste Incineration

Hazardous waste incineration occurs at on-site hazardous waste incinerators, commercial hazardous waste incinerators, mobile hazardous waste incinerators, and some boilers and industrial furnaces (BIFs). The quantity of hazardous waste that is destroyed in incinerators and the types of incinerators used is poorly documented.

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The activity data for benzene were derived from total quantities of incinerable hazardous waste generated. In 1992, approximately 2.5 million metric tons of hazardous waste were generated.¹ Dempsey and Oppelt (1993) estimate that of the total amount of hazardous waste generated, 1.3 million metric tons were burned in dedicated hazardous waste facilities, and 1.2 million metric tons were burned in BIFs.²

Assumptions on Process and Control Levels

Oppelt (1987) provides a table that shows the different types of hazardous waste incinerator control devices and their distribution among incinerators.³ Approximately 30 percent of all hazardous waste incinerators control emissions with a Venturi scrubber. The emission factor used to develop national emissions for benzene is representative of an incinerator with miscellaneous control devices (Venturi, packed, and ionized scrubbers; carbon bed filters, and HEPA filters).

Emission Factors

Table A.17 lists the emission factor that was used to develop the national emissions estimate for hazardous waste incineration. The emission factor was obtained from the FIRE database.⁴

Table A.17. Hazardous Waste Incineration Emission Factors

Pollutant	Emission Factor	Units
Benzene	1.23×10^{-3}	lb/ton waste burned

Major/Area Assumptions

A major/area split of 100/0 is assumed. It is estimated that approximately 25 percent of all hazardous waste incinerated is sent to 20 commercially permitted hazardous waste incinerators; these facilities are assumed to be major sources due to HAP emissions. The BIFs are considered major sources due to co-location at industrial facilities which are major sources due to their industrial processes.

Approach and Assumptions for Spatial Apportionment

National emissions were apportioned to the State and county level using the number of facilities in SIC codes 20-39 and 49 (manufacturing and electric, gas, and sanitary services).

REFERENCES FOR HAZARDOUS WASTE INCINERATION

1. Oppelt, E.T. 1987. Incineration of Hazardous Waste. A Critical Review. JAPCA. 37(5):558-586. p. 559.
2. Dempsey, C.R. and Oppelt, E.T. 1993. Incineration of Hazardous Waste: A Critical Review Update. Air and Waste. 43:25-73.
3. Oppelt, E.T. 1987. Incineration of Hazardous Waste. A Critical Review. JAPCA. 37(5):558-596. p. 565.
4. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.

A.18 Medical Waste Incineration

The Resource Conservation and Recovery Act (RCRA), 1976, defines medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in production or testing of biologicals." The incineration of medical waste occurs at: hospitals, laboratories, veterinary facilities, nursing homes and at commercial incinerators. Hospital incinerators are the most common type of medical incinerator and burn more waste than other medical waste incinerator types.¹

Medical waste incinerators vary widely in capacity. Incinerators operate continuously or intermittently, based on waste loading rates and incinerator type.

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

Three types of incinerators are used to burn medical wastes: controlled air, excess air, and rotary kiln. About 95 percent of these are controlled air incinerators.² There are approximately 5,000 medical waste incinerators in the United States.¹ Using facility capacities, it was estimated that about 1.64×10^6 metric tons of medical waste were incinerated in 1990.³

Assumptions on Process and Control Levels

Medical waste incinerators have primarily been operated without add-on pollution control devices; only 2 percent currently utilize emission controls.² The emission factors used to develop national emissions for the 112(k) inventory were based on emissions data from uncontrolled incinerators.⁴

Emission Factors

Table A.18 lists the emission factors for each pollutant that were used to develop the national emissions estimates for medical waste

Table A.18. Medical Waste Incineration Emission Factors

Pollutant	Emission Factor	Units
Benzene	4.92×10^{-3}	lb/ton waste burned
Formaldehyde	1.6×10^{-3}	lb/ton waste burned

incineration. The emission factors are for uncontrolled medical waste incinerators and were obtained from CARB and FIRE.^{4,5}

Major/Area Assumptions

Although most medical waste incinerators are operated without add-on air pollution control devices, most are too small to be major sources. Hydrogen chloride (HCl) is one of the pollutants emitted in large quantities from medical waste incinerators.⁶ Average facility capacities¹ and an HCl emission factor for a controlled air incinerator without add-on pollution controls² were used to estimate that approximately 85 percent of medical waste incinerators are area sources. The remaining 15 percent are estimated to be major sources since these facilities have the potential to emit 10 tons per year of HCl.

Approach and Assumptions for Spatial Apportionment

Total national emissions were allocated to the State and county level using the number of employees in each State associated with nursing and personal care facilities, hospitals, and medical laboratories (SIC codes 8050, 8060, and 8070).

REFERENCES FOR MEDICAL WASTE INCINERATION

1. U.S. EPA. April 1992. Medical Waste Incinerators - Background Information for Proposed Standards and Guidelines: Industry Profile Report for New and Existing Facilities. Draft. p. 2.
2. U.S. EPA. 1994. Compilation of Air Pollutant Emission Factors, Fifth Edition, Section 2.3: "Medical Waste Incineration." Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
3. U.S. EPA. September 30, 1991. Medical Waste Incinerators - Background Information for Proposed Standards and Guidelines: Environmental Impacts Report for New and Existing Facilities. Draft. pp. 54 and 61.
4. CARB. Confidential Report No. ERC-53.

5. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
6. U.S. EPA. June 1993. Locating and Estimating Air Toxic Emissions from Medical Waste Incinerators. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-454/R-93-053.

A.19 Sewage Sludge Incineration

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emission Estimates

There are approximately 199 operating sewage sludge incinerators in the United States.¹ More than 80 percent of the facilities are multiple hearth incinerators.² In 1992, approximately 8.65×10^5 metric tons of dry sewage sludge was incinerated.¹

Assumptions on Process and Control Levels

Multiple hearth sewage sludge incinerator emissions are usually controlled by a venturi scrubber or an impingement tray scrubber.³

Emission Factors

The emission factors represent sources with miscellaneous scrubbers.^{4,5} Table A.19 lists the emission factors for each pollutant that were used to develop the national emissions estimates for sewage sludge incineration.

Table A.19. Sewage Sludge Incineration Emission Factors

Pollutant	Emission Factor	Units
Benzene	3.4×10^{-4}	lb/ton dry sludge
Formaldehyde	9.7×10^{-4}	lb/ton dry sludge

Major/Area Assumptions

It was assumed that all sewage sludge incinerators are area sources located in urban areas. This assumption takes into account the other emissions that can occur at waste treatment facilities such as HAPs from aeration basins, and metals, chlorine, and chloroform emissions from incineration. Emission estimates developed for a typical sewage sludge

incinerator using conservative assumptions found that HAP emissions are far below 25 tons per year.

Approach and Assumptions for Spatial Apportionment

National sewage sludge incineration emissions were apportioned to the State level using the number of sewage sludge incinerators in each State.⁶ The number of facilities in each State were adjusted using more accurate information on the number of operating sewage sludge incinerators in each Region.¹ It was assumed that all sewage sludge incinerators have similar emissions. All sewage sludge incineration is assumed to occur in URBAN-1 areas because large numbers of sludge incinerators are located in the northeastern United States where population density is high and land area for waste disposal is limited.

REFERENCES FOR SEWAGE SLUDGE INCINERATION

1. Federal Register. February 19, 1993. Standards for the Use or Disposal of Sewage Sludge; Final Rules. F.R. 58; 9248-9404.
2. U.S.EPA. July 1993. Emission Factor Documentation for AP-42 Chapter 2.5 Sewage Sludge Incineration. p. 2.5-1.
3. U.S. EPA. July 1993. Emission Factor Documentation for AP-42 Chapter 2.5 Sewage Sludge Incineration. p. 2.5-4.
4. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
5. U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
6. U.S. EPA. 1990. Locating and Estimating Air Toxicities Emissions from Sewage Sludge Incinerators. EPA-450/2-90-009. p. 3-2.

A.20 Municipal Waste Combustion

There are three main types of municipal waste incinerators in the United States: mass burn (MB), refuse derived fuel (RDF), and modular combustors (MOD). Mass burn combustors are the most common type of combustor, representing 54 percent of all municipal waste combustors (MWCs) in the United States, followed by modular facilities (32 percent) and RDF facilities (13 percent).¹

According to the 1994 Maximum Achievable Control Technologies (MACT) Study, there are 179 existing MWC facilities with design capacities above 38.6 tons/day. The facilities designed to burn less than 38.6 tons/day account for less than one percent of the total waste flow to MWC facilities.² Of the total MWC capacity in the United States, about 58 percent of municipal waste is treated in mass burn facilities, 29 percent in RDF-fired facilities, 9 percent in modular combustors, and 4 percent in other MWC designs.³

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

A study conducted by the Office of Solid Waste estimated that 3.2×10^7 tons of municipal solid waste were combusted in 1991.⁴

Assumptions on Process and Control Levels

Emissions from MWCs are controlled by electrostatic precipitators (ESPs), spray dryers, and fabric filters. According to the MACT study, more ESPs are used by MWCs (44 percent) to control emissions than any other control devices. The emission factor used to determine national emissions for the 112(k) inventory reflects a multiple chamber MWC with an ESP or scrubber in place.

Emission Factors

Two emission factors for formaldehyde emissions (one controlled with scrubber and one controlled with ESP) were obtained from the FIRE database.⁵ The two emission factors were averaged.

Table A.20 lists the emission factor for formaldehyde that was used to develop the national emissions estimate for municipal waste incineration.

Table A.20. Municipal Waste Combustion Emission Factors

Pollutant	Emission Factor	Units
Formaldehyde	2.104×10^{-3}	lb/ton of waste burned

Major/Area Assumptions

Approximately 95 percent of all municipal waste incinerators are major sources due to hydrogen chloride (HCl) emissions.^{6,7}

Approach and Assumptions for Spatial Apportionment

National emissions will be allocated to the State level using each State's municipal waste combustion capacity.⁸ State level emissions will be distributed between individual counties based on the number of facilities in each county that are associated with SIC code 4950 (sanitary services).

REFERENCES FOR MUNICIPAL WASTE COMBUSTION

1. U.S. EPA. January 1992. Economic Impact and Preliminary Regulatory Impact Analysis for Proposed MACT-Based Emission Standards and Guidelines for Municipal Waste Combustors. EPA-450/3-91-029. U.S. EPA, Office of Air and Radiation. p. 3-9.
2. U.S. EPA. January 1992. Economic Impact and Preliminary Regulatory Impact Analysis for Proposed MACT-Based Emission Standards and Guidelines for Municipal Waste Combustors. EPA-450/3-91-029. U.S. EPA, Office of Air and Radiation. p. 3-8.
3. U.S. EPA. April 1989. Locating and Estimating Air Toxicities Emissions from Municipal Waste Combustors. EPA-450/2-89-006. U.S. EPA, Office of Air and Radiation. p. 3-1.
4. U.S. EPA. July 1992. Characterization of Municipal Solid Waste in the United States: 1992 Update. EPA/530-R-92-019. U.S. EPA, Office of Solid Waste and Emergency Response. p. ES-5.
5. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
6. Memorandum to Walt Stevenson, EPA/SDB, from Denise Fenn and Kris Nebel, Radian Corporation. August 20, 1992. Information on the Municipal Waste Combustion Database.
7. U.S. EPA. August 1989. Municipal Waste Combustors - Background Information for Proposed Guidelines for Existing Facilities. EPA/450-3-89-27e. pp. 6-66 - 6-67.

8. U.S. EPA. September 1992. Emission Factor Documentation for AP-42 Section 2.1 - Refuse Combustion. U.S EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. p. 2-3.

A.21 Stationary Turbines - Natural Gas Internal Combustion

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for natural gas-fired turbines within the stationary internal combustion source category in the base year 1990 is 562×10^9 cubic feet of natural gas.¹ This national activity level includes natural gas consumed by gas-fired turbines in the industrial and electric utility sectors and is derived from the total national consumption of natural gas as reported by EIA for 1990. Based on information from the EPA's Environmental Assessment of Stationary Internal Combustion Systems,² approximately 3 percent of the total national natural gas consumption in 1985 was associated with gas-fired turbines; this percentage was used to calculate the fraction of the 1990 natural gas consumption for gas-fired turbines.

Assumptions on Process and Control Levels

The emission factor presented is based on emissions from gas-fired turbines controlled with catalytic reduction.

Emission Factors

Table A.21 lists the emission factor for benzene that was used to develop the national emissions estimates for natural gas-fired turbines. The emission factor for benzene was obtained from the FIRE database.³

Table A.21. Stationary Turbines - Natural Gas Internal Combustion Emission Factors

Pollutant	Emission Factor	Units
Benzene	5.5×10^{-8}	ton/MMBtu heat input

Major/Area Assumptions

The category of natural gas-fired stationary internal combustion sources is assumed to consist of 60 percent major sources and 40 percent area sources. While no single turbine emits more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs, these units are co-located at industrial facilities and electric utility plants that are major sources. Assuming that 50 percent of the industrial sector consists of major sources and 100 percent of the electric utilities are major sources, then based on the relative consumption of natural gas for these two sectors as described above, the estimate of 60 percent major sources and 40 percent area sources was derived.

Approach and Assumptions for Spatial Apportionment

A national benzene emission estimate for gas-fired stationary internal combustion sources was apportioned to the county level using the county to nation ratio of employment for SIC codes 20-39 (manufacturing industries) and SIC code 4911 (electric services) from the U.S. Bureau of Census database developed for this inventory.⁴ County emissions were then assigned to one of the three population subcategories (URBAN-1, URBAN-2, and RURAL) based on the county classification.

REFERENCES FOR STATIONARY TURBINES - NATURAL GAS INTERNAL COMBUSTION

1. Energy Information Administration. May 1992. State Energy Data Report, Consumption Estimates 1960-1990. DOE/EIA-0214(90). Office of Energy Markets and End Use, Washington, DC. p. 22.
2. U.S. EPA. February 1979. Emissions Assessment of Conventional Stationary Combustion Systems, Volume II: Internal Combustion Sources. EPA-600/7-79-029C. U.S. EPA, Industrial Environmental Research Laboratory, Research Triangle Park, NC. pp. 143 - 146.
3. U.S. EPA. 1995. Factor Information Retrieval (FIRE) System Database. Version 5.1.
4. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.22 Forest Fires/Prescribed Burning

Pollutants Addressed

- Benzene;
- 1,3-Butadiene; and
- Formaldehyde.

National Activity Level/Emission Estimates

Emission estimates attributed to forest fires and prescribed burning were based partially on a methodology developed by EPA's Office of Health Exposure and Assessment.¹ An average of 5.1 million acres of biomass (vegetation) are burned in forest fires each year in the U.S., based on 40 years of USDA Forest Service data. In 1989, 5.1 million acres were burned as a result of prescribed burning. Biomass consumption rates were estimated at 10.4 tons/acre for forest fires, and 8.2 tons/acre for prescribed fires. From these estimates, the national activity level for forest fires was estimated at 53 million tons of biomass consumed and for prescribed fires was estimated at 42 million tons for a total of 97 million tons.

The emission factors presented below were used in conjunction with the activity data to estimate national emissions.

Assumptions and Control Levels

No controls are used to reduce emissions from forest fires and prescribed burning.

Emission Factors

Table A.22 lists the emission factors for each pollutant that were used to develop the national emissions estimate for forest fires and prescribed burning.^{2,3} Emission factors for emissions from forest fires and prescribed burns were obtained from the 1993 Puget sound study² and a report prepared by Janice Peterson and Darold Ward for the USDA Forest Fire Service.³ The emission factors vary according to fuel type (i.e., flaming versus smoldering wood or duff and live vegetation). Because no information was available to characterize, on a national basis, the percentages of the specific types of fuels burned in forest fires and prescribed burns, certain assumptions were made in utilizing the emission factors to calculate national

emissions. The national estimate is calculated based on flaming wood and duff and smoldering wood and duff. It was assumed that, on a national basis, during prescribed burns and forest fires 75 percent of biomass (wood and duff) is burned under flaming conditions and 25 percent of biomass (wood and duff) is burned under smoldering conditions.

Table A.22. Forest Fires/Prescribed Burning Emission Factors

Pollutant	Emission Factor	Units
Benzene		
Flaming	0.33	g/Kg
Smoldering	1.26	g/Kg
1,3-Butadiene		
Flaming	0.12	g/Kg
Smoldering	0.45	g/Kg
Formaldehyde		
Flaming	0.75	g/Kg
Smoldering	2.9	g/Kg

The following calculations were carried out to determine national benzene emissions from forest fires. However, the national emissions from prescribed burning were obtained from a prescribed fire emissions inventory developed from Ward and Peterson's methodology.³

Example Calculation (Benzene):

Annual National Emissions = emissions from forest fires
= $[(3.33 \times 10^{-4} \text{ tons/ton flaming wood and duff burned}) \times (39,750,000 \text{ tons flaming wood and duff burned in forest fires/yr})] + [(1.26 \times 10^{-3} \text{ tons/ton smoldering wood and duff burned}) \times (13,250,000 \text{ tons smoldering wood and duff burned in forest fires/yr})]$
= 29,932 tons/yr
Annual National Emissions = emissions from prescribed burning
= 25,685 tons/yr

Major/Area Assumptions

Forest fires and prescribed burning are assumed to be exclusively area sources.

Approach and Assumptions for Spatial Apportionment

Statistics were obtained on the number of acres of Federal, State, and private lands burned in forest fires for 1990.³ Data were also obtained on the number of acres burned each year from prescribed burning.⁴ The total number of acres for both wildfires and prescribed burning was combined, and total national emissions for forest fires were apportioned on a State basis.

REFERENCES FOR FOREST FIRES/PREScribed BURNING

1. U.S. EPA. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, and Occurrence and Background Exposures. External Review Draft. Office of Health and Environmental Assessment, Washington, D.C. EPA-600/6-88-55b. June 1994.
2. U.S. EPA. May 1994. Evaluation and Improvement of the Puget Sound Toxic Air Contaminants Emissions Inventory. Technical Note. Office of Research and Development, Washington, DC.
3. Peterson, J. and D. Ward, 1989. An Inventory of Particulate Matter and Air Toxic Emissions from Prescribed Fires in the United States for 1989. U.S. Department of Agriculture, Forest Service.
4. 1984-1990 Forest Fire Statistics. United States Department of Agriculture - Forest Service.

A.23 Structure Fires

Structure fires are a source of a number of HAPs, although emissions data for only one 112(k) pollutant, formaldehyde, were obtained. Emissions from structure fires depend on the type of structure, type of materials contained, and the amount of materials combusted. Emissions from structure fires were estimated using data from an experimental fire,¹ information from a study on municipal waste combustion,² and information presented in EPA Test Method 19.^{3,4} The data from the experimental fire included the types and weights of materials combusted and pollutant concentrations in the effluent gases. The municipal waste combustion study included highest heating values (HHVs) for various combustible materials, and EPA Method 19 presented fuel factors for several combustible materials.

Pollutant Addressed

- Formaldehyde

Emission Estimates

A list of HHVs for various combustible materials is presented in Table A.23-1.² These values were assigned to the various materials consumed in the experimental fire based on the type of material. The heat input from each type of material was determined by multiplying the assigned HHV by the weight of the material. The heat inputs from all materials were summed and then divided by the sum of all material weights to obtain a weighted average HHV. Assuming that all materials are consumed in a fire, this value represents the average HHV of the materials. The following equation was used to estimate a weighted-average HHV for materials consumed in a structure fire:

$$\text{Weighted-average HHV } \frac{\text{Btu}}{\text{lb}} = \frac{\sum \left(\text{HHV} \left(\frac{\text{Btu}}{\text{lb}} \right) \text{ assigned to material} \right) \left(\frac{\text{material weight}}{\text{lb}} \right)}{\text{weight of total materials (lb)}}$$

Table A.23-2 presents the weighted-average HHV for materials consumed in a structure fire.

Table A.23-1. Heating Values of Combustible Materials^a

Material	HHV (Btu/lb)
Newsprint	7,979
Corrugated containers	7,047
Office papers	6,572
Other paper and paperboard	6,644
Glass containers	64
Other glass	64
Steel cans	122
Other ferrous	122
Aluminum cans	122
Other aluminum	122
Other nonferrous metals	122
PET (soft drink) bottles	10,933
Milk bottles	18,690
Other plastic containers	16,420
Other plastics	17,858
Rubber and leather	12,800
Textiles	9,390
Wood	7,329
Other	2,800
Food wastes	2,840
Yard wastes	2,876
Miscellaneous and inorganic wastes	122

^a Kilgroe et al., 1991.

Table A.23-2. Btu-Weighted Average of Combustible Materials (HHV/lb)

Material	Weight (lb)	Total Material (Btu)
Fixed combustibles ^b	770.0	5,643,330
Chest of drawers	138.6	1,015,799
Desk	90.2	661,076
Chair	8.8	64,495
Bookcase	57.2	419,219
Foot warmer	24.2	227,238
Shoes case	44.0	563,200
Television set	59.4	1,060,765
Telephone	4.4	78,575
Carpet (PAN)	13.2	123,948
Curtains (PAN, Polyester)	24.4	436,092
Beddings (PAN, PA, Polyester)	62.5	1,115,768
Mattress (flexible urethane foam)	18.5	330,016
Pillows (synthetic)	4.8	86,433
Blankets (PAN)	16.3	290,728
Clothes (PAN, PA, Polyester)	36.3	648,245
PVC sheets	4.4	78,575
Artificial leather	10.8	192,509
Newspapers	22.0	175,538
Books	220.0	1,461,680
Wood sticks	24.2	177,362
Plywood	60.1	440,180
Rigid urethane foam	15.4	275,013
PVC wallpaper	8.8	157,150
TOTAL	1738.4	15,722,936

^a Morikawa et al., 1987.

^b Built-in closets, cabinets, window frames, etc. Reference does not list a specific HHV for these components; therefore, the HHV listed for wood is used.

After determining the weighted-average HHV for material consumed in a structure fire, HAP emissions were determined using pollutant concentrations in effluent gases from an experimental ferro-concrete building fire reported in the paper entitled "Toxicity Evaluation of Fire Effluent Gases from Experimental Fires in a Building."¹ Each pollutant concentration was converted from parts per million (ppm) to pounds per dry standard cubic feet (dscf) by using the molecular weight of the pollutant and applying the Ideal Gas Law. The paper did not contain sufficient information to estimate an average concentration for each HAP compound; therefore, the maximum concentrations reported in the paper were used. These adjusted compound concentrations are presented in Table A.23-3.

Table A.23-3. Pollutant Concentrations in Effluent Gases^a

Chemical Compound	Concentration (lb/dscf)
Formaldehyde	5.91 x 10 ⁻⁶

^aMorikawa et al., 1987.

The following equation was used to adjust compound effluent concentrations:

$$\text{Effluent HAP concentration} \left(\frac{\text{lb}}{\text{dscf}} \right) = \frac{\left(\text{HAP concentration (ppm)} \right) \left(\frac{[21-0]}{21 - (\text{measured O}_2 \text{ percent})} \right) \left(\frac{\text{HAP molecular weight}}{385,000,000} \right)}{1}$$

The following is an example calculation (using formaldehyde) of the calculations used to adjust compound effluent concentrations:

$$\text{Formaldehyde concentration} = \frac{(65 \text{ ppm}) [(21-0)/(21-3)] (30)}{385,000,000} = 5.91 \times 10^{-6} \frac{\text{lbs}}{\text{dscf}}$$

Data obtained from the National Fire Prevention Association indicate that 637,500 fires in homes and businesses occurred in 1992 (latest year available).⁵ The annual number of fires was then multiplied by the amount of material consumed per fire (6.8 tons, according to the Illinois EPA) in order to estimate the total of material combusted per year nationally.

The total heat input (Btu) generated from materials combusted was estimated by multiplying the amount of materials consumed by the average HHV. As shown in the following equation, the total Btu estimate was multiplied by a

fuel-factor (F-factor) for municipal waste to obtain the total volume of gases generated.³

$$\begin{array}{l} \text{National volume of effluent} \\ \text{gas generated} \\ \text{(dscf)} \end{array} = [\text{F-factor (dscf/MMBtu)}] * [\text{Total Heat Input (MMBtu)}]$$

Table A.23-4 presents the estimated volume of effluent gas generated nationally per year and other supporting data. To determine HAP emissions,

Table A.23-4. Volume of Effluent Gas Generated Per Year and Supporting Data^{a,b,c}

Number of structure fires per year	637,500
Tons of combustibles consumed per fire	6.8
Total combustibles consumed per year	4,335,000
Heat input, Exp. 1 (MMBtu)	66,507,080
Heat input, Exp. 2 (MMBtu)	78,413,895
F-Factor (dscf/MMBtu)	9,570
Effluent gas generated, Exp. 2 (dscf)	7.50×10^{11}

^aFederal Register. Vol. 52, No. 241. December 16, 1987.

^bU.S. EPA. October 1994. Air Toxic Emission Inventories for the Chicago Area. Draft Report. Washington, DC.

^cCommunication from Nancy Swartz, National Fire Prevention Association, to Eric Goehl, Radian Corporation, August 26, 1994.

the HAP concentration for each compound was multiplied by the volume of effluent gas generated per year. The following equation was used to determine national HAP emissions from structure fires:

$$\begin{array}{l} \text{(National volume of effluent gas generated)} * \text{(HAP concentration)} \\ = \text{Annual National Emissions} \end{array}$$

Assumptions on Process and Control Levels

Structure fires are uncontrolled emission sources.

Emission Factors

From the previous calculations, a per capita emission factor for formaldehyde of 8.915×10^{-6} tons/person was developed.

Major/Area Assumptions

Structure fires are considered area sources.

Approach and Assumptions for Spatial Apportionment

National emissions were apportioned to States based on State population of URBAN 1, URBAN 2, and RURAL populations.

REFERENCES FOR STRUCTURE FIRES

1. Morikawa, T., E. Yanai, and T. Nishina. 1987. Toxicity Evaluation of Fire Effluent Gases from Experimental Fires in a Building. *Journal of Fire Science*. 5:248-270.
2. Kilgroe, J.D., T.G. Brna, A. Finkelstein, and R. Klicius. 1991. The Effects of Changing Municipal Solid Waste Characteristics on Combustion Fuel Quality. Presented at U.S. EPA Municipal Waste Combustion Conference in Tampa, Florida.
3. Federal Register. Vol. 52, No. 241. December 16, 1987.
4. U.S. EPA. October 1994. Air Toxic Emission Inventories for the Chicago Area. Draft report. Washington, DC.
5. Communication from Nancy Swartz, National Fire Prevention Association, to Eric Goehl, Radian Corporation, August 26, 1994.

A.24 Gasoline Distribution - Bulk Plants and Terminals (Stage I)

The gasoline distribution network consists of storage and transfer facilities that move gasoline from its production to its end consumption. The network includes tanker ships and barges, pipelines, tank trucks and rail cars, storage tanks and service stations. Finished gasoline is distributed from refineries in a complex system comprised of wholesale and retail outlets. Stage I distribution concerns gasoline storage and loading operations at refineries, transfers to bulk terminals via pipelines, ships, or barges, and shipment of gasoline to intermediate bulk storage facilities known as bulk plants and deliveries via tanker trucks to retail service stations.

Air pollutants are emitted throughout the gasoline distribution network, particularly at points of transfer. Of the pollutants emitted, benzene is the only HAP of those included in this survey that has been detected in Stage I emissions. National benzene emissions estimates in this survey were calculated by speciating the VOC emission estimates provided in the NESHAP on Gasoline Distribution Industry (Stage I) - Background Information for Proposed Standards (Stage I NESHAP).¹

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The Stage I NESHAP used fuel throughput as activity data. Fuel throughput data were taken from the U.S. Department of Energy, Energy Information Administration's Petroleum Supply Monthly, January 1991. This report quantifies gasoline consumption for 1989 to be 112.7 billion gallons. It should be noted that this value does not compare with the U.S. Department of Transportation Highway Statistics 1990 that quantifies gasoline utilization to be 131.6 billion gallons.² Table A.24 presents the gasoline throughput and estimated benzene emissions by State.

Assumptions on Process and Control Levels

The main focus of the Stage I NESHAP was to compare alternative emission reduction strategies for the base year 1988. Emission estimates for 1990 were not provided in this report. For this 112(k) survey, 1988 NESHAP emission estimates were adjusted to reflect emissions in 1990 by considering

Table A.24. Gasoline Distribution Stage I State Benzene Emissions

State	Gasoline Throughput (x 1000 gal/year)	Benzene (tons/year)
Alabama	2624410	200
Alaska	319675	20
Arizona	1968916	150
Arkansas	1589613	120
California	14660663	1130
Colorado	1696690	130
Connecticut	1487912	110
Delaware	385744	30
District of Columbia	188331	10
Florida	6674542	520
Georgia	4323011	330
Hawaii	386683	30
Idaho	593134	50
Illinois	6187208	480
Indiana	3315936	260
Iowa	1672095	130
Kansas	1494668	120
Kentucky	2269560	180
Louisiana	2165512	170
Maine	689243	50
Maryland	2319757	180
Massachusetts	2596509	200
Michigan	4678582	360
Minnesota	2207077	170
Mississippi	1524871	120
Missouri	3278949	250
Montana	536064	40
Nebraska	960089	70
Nevada	759189	60
New Hampshire	545268	40
New Jersey	3697628	290

Table A.24 (Continued)

State	Gasoline Throughput (x 1000 gal/year)	Benzene (tons/year)
New Mexico	999775	80
New York	6678597	520
North Carolina	3838565	300
North Dakota	403229	30
Ohio	5589810	430
Oklahoma	2031581	160
Oregon	1654642	130
Pennsylvania	5436631	420
Rhode Island	401575	30
South Carolina	2189277	170
South Dakota	459089	40
Tennessee	3026595	230
Texas	9878988	760
Utah	880258	70
Vermont	321099	20
Virginia	3483245	270
Washington	2593986	200
West Virginia	1006325	80
Wisconsin	2453244	190
Wyoming	459014	40
Total	131,583,054	10,160

the projected 1998 fuel consumption (117.9 billion gallons) provided in the NESHAP with the Department of Energy's 1990 fuel consumption (110.5 billion gallons). This approach assumes that the 6.28 percent reduction in fuel consumption between 1998 and 1990 is associated with a similar reduction in estimated emissions. Adjustments made in the NESHAP document for the level of control projected in 1988 and anticipated future uses of alternative fuels could not be taken into consideration when 1998 emissions were adjusted to 1990 in this survey, such that emission estimates made in this survey may slightly underestimate actual emissions.

Emission Factors

The Stage I NESHAP provided VOC emission factors and estimated national annual VOC and HAP emissions for different processes throughout the Stage I gasoline distribution network. These values were adjusted relative to projected control programs in each State, yielding a national annual HAP estimate of 57,816 tons per year for 1998. According to the vapor profile for gasoline found in the Stage I NESHAP, benzene is 18.75 percent of the total HAP emission. Taking this into consideration, national annual benzene Stage I emissions are 10,840 tons for 1998. This estimate was adjusted to reflect emissions in 1990, yielding a national annual benzene estimate of 10,160 tons.

Major/Area Assumptions

The Stage I NESHAP provided total HAP emissions for facilities within the gasoline network, except bulk terminals where insufficient data are available. None of the typical facilities considered had HAP emissions sufficiently large to be classified as a major source. Bulk terminals may be major sources, but insufficient data were provided to fully assess these sources.

Approach and Assumptions for Spatial Apportionment

National emissions were allocated to counties based on county proportion of national employment associated with SIC code 5171, petroleum bulk stations and terminals.

REFERENCES FOR GASOLINE DISTRIBUTION - BULK PLANTS AND TERMINALS (STAGE I)

1. U.S. EPA. 1994. Gasoline Distribution Industry (Stage I) - Background Information for Proposed Standards, Washington, DC.
2. U.S. Department of Transportation. 1991. Highway Statistics 1990, Washington, DC.

A.25 Gasoline Distribution - Local Gas Stations and Refilling/Refueling (Stage II)

The majority of VOCs emitted at gasoline service stations occur when fuel is being transferred either during the refilling of underground storage tanks or during vehicle refueling. These emissions are primarily due to the displacement of vapors by fuel entering the tanks (i.e., underground storage or vehicle fuel tanks). A smaller amount of organics are released due to spillage during fuel transfer and tank breathing. These emissions that are associated with loading of service station underground tanks are considered to be part of Gasoline Distribution - Stage I, and those emissions that are associated with vehicle refueling are considered to be part of Gasoline Distribution - Stage II.

Benzene is the only HAP included in this report that has been detected during vehicle refueling. It is possible to estimate these emissions by using the approach recommended in the U.S. EPA/OAQPS's Technical Guidance - Stage II Vapor Recovery Systems for Control of Vehicle Refueling Emissions at Gasoline Dispensing Facilities (Stage II Guidance).¹ This report defines State specific VOC emission factors relative to monthly temperatures. These VOC emission factors can be applied to State highway fuel throughput to estimate emissions. VOC emissions can be speciated by using speciation values from Stage II Guidance.

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

To estimate emissions using the approach outlined in Stage II Guidance, State highway fuel data are required. Highway fuel usage data were obtained from the U.S. Department of Transportation's Highway Statistics 1990 (see Table A.25).²

Assumptions on Process and Control Levels

The emission factors used in the Stage II Guidance do not include spillage or underground tank breathing losses. The emissions from these two events are assumed to be small (< 1 percent of the total refueling emissions; 120 mg/l for breathing losses and 55 mg/l for spillage).

Table A.25. Emissions from Gasoline Distribution - Stage II

State	Average Annual VOC Emission Rate (E _r)		1990 Throughput (Million gal/yr)	Benzene Refueling Emissions (tons/yr)
	mg/l	lb/gal		
Alabama	1630	0.013601	2624410	161
Alaska	1740	0.014519	319675	21
Arizona	1220	0.010180	1968916	90
Arkansas	1630	0.013601	1589613	97
California	1470	0.012266	14660663	809
Colorado	1200	0.010013	1696690	76
Connecticut	1290	0.010764	1487912	72
Delaware	1260	0.010514	385744	18
District of Columbia	1250	0.010430	188331	9
Florida	1650	0.013768	6674542	414
Georgia	1630	0.013601	4323011	265
Hawaii	1350	0.011265	386683	20
Idaho	1150	0.009596	593134	26
Illinois	1260	0.010514	6187208	293
Indiana	1270	0.010597	3315936	158
Iowa	1350	0.011265	1672095	85
Kansas	1230	0.010264	1494668	69
Kentucky	1230	0.010264	2269560	105
Louisiana	1620	0.013518	2165512	132
Maine	1290	0.010764	689243	33
Maryland	1280	0.010681	2319757	111
Massachusetts	1290	0.010764	2596509	126
Michigan	1290	0.010764	4678582	227
Minnesota	1360	0.011348	2207077	113
Mississippi	1630	0.013601	1524871	93
Missouri	1290	0.010764	3278949	159
Montana	1340	0.011181	536064	27
Nebraska	1300	0.010848	960089	47
Nevada	1460	0.012183	759189	42
New Hampshire	1290	0.010764	545268	26
New Jersey	1300	0.010848	3697628	180

Table A.25. (Continued)

State	Average Annual VOC Emission Rate (E_r)		1990 Throughput (Million gal/yr)	Benzene Refueling Emissions (tons/yr)
	mg/l	lb/gal		
New Mexico	1270	0.010597	999775	48
New York	1290	0.010764	6678597	324
North Carolina	1380	0.014019	3838565	242
North Dakota	1350	0.011265	403229	20
Ohio	1260	0.010514	5589810	264
Oklahoma	1360	0.011348	2031581	104
Oregon	1180	0.009846	1654642	73
Pennsylvania	1290	0.010764	5436631	263
Rhode Island	1290	0.010764	401575	19
South Carolina	1670	0.013935	2189277	137
South Dakota	1290	0.010764	459089	22
Tennessee	1680	0.014019	3026595	191
Texas	1300	0.010848	9878988	482
Utah	1510	0.012600	880258	50
Vermont	1290	0.010764	321099	16
Virginia	1240	0.010347	3483245	162
Washington	1210	0.010097	2593986	118
West Virginia	1260	0.010514	1006325	48
Wisconsin	1270	0.010597	2453244	117
Wyoming	1300	0.010848	459014	12
Total			131,583,054	6,826

The estimates provided in this study are conservative, because they assume that all fuel throughput is via conventional refueling methods and do not take into consideration any Stage II emission controls such as the vapor balance system, the Hasstech assist system, the Hirt assist system, or the Amoco Bellowless Nozzle system.

Emission Factors

The emission factors developed in Stage II Guidance are based on the following empirically derived equation:

$$E_r = 264.2 [(-5.9909) - 0.0949 (\Delta T) + 0.0884 (T_d) + 0.485 (RVP)]$$

E_r = Emission rate, milligrams of VOC per liter of liquid loaded (mg/l)

RVP = Reid vapor pressure (psia)

ΔT = Difference between the temperature of the fuel in the automobile tank and the temperature of the dispensed fuel, ($^{\circ}\text{F}$).

T_d = Dispensed fuel temperature, ($^{\circ}\text{F}$).

In Stage II Guidance, E_r values were calculated for each State by month. These monthly E_r values were weighted and averaged to approximate an annual VOC emission factor for each State (see Table A.25). These annual emission factors were applied to annual State highway fuel usage to estimate VOC emissions.

VOC emissions were speciated for a number of hazardous air pollutants, including benzene, in the Stage II Guidance. The arithmetic average for benzene as a weight percent ratio of VOC Emissions for normal fuel (0.9 percent) was applied to the VOC emission total to estimate benzene emissions.

Major/Area Assumptions

This report estimates national benzene emissions to be 6,826 tons per year and there are 210,120 retail service stations operating in the United States as of 1990. The average annual benzene emissions for a retail service station is 0.033 tons. Because these emissions are less than 10 tons per year, gasoline service stations are considered to be area sources.

Approach and Assumptions for Spatial Apportionment

Using the estimating approach in Stage II Guidance, State fuel throughput can be multiplied by the emission factors (E_r) to estimate total State

VOC emissions for vehicle refueling. These VOC emissions can be speciated to obtain total State benzene emissions (see Table A.25). These State emission values can be allocated within the State relative to population. The State population that is considered rural, as defined in the U.S. Department of Commerce 1990 Census, can be allocated a percent of the refueling emissions relative to their percent of the State population, and the remainder of the emissions can be allocated to the urban population centers within the State.

REFERENCES FOR GASOLINE DISTRIBUTION - LOCAL GAS STATIONS AND REFILLING/ REFUELING (STAGE II)

1. U.S. EPA. 1991. Technical Guidance - Stage II Vapor Recovery Systems for Control of Vehicle Refueling Emissions at Gasoline Dispensing Facilities, OAQPS, Research Triangle Park, NC.
2. U.S. Department of Transportation. 1991. Highway Statistics 1990, Washington, DC.

A.26 Petroleum Refining

Petroleum refineries include facilities that produce gasoline, naphthas, kerosene, jet fuels, distillate fuel oils, residual fuel oils, lubricants, and other products from crude oil or unfinished petroleum derivatives. These products are produced by separating petroleum or separating, cracking, or reforming unfinished petroleum derivatives. Emission sources at these facilities include process vents, equipment leaks, wastewater treatment, storage tanks, and transfer operations. According to the 1994 MACT study done in conjunction with the Petroleum Refineries NESHAP, there are 190 petroleum refineries in operation.¹

Pollutants Addressed

- 1,3-Butadiene; and
- Benzene.

National Activity Level/Emission Estimates

The Petroleum Refineries NESHAP provided VOC and total HAP emissions estimates for process vents, equipment leaks, wastewater treatment, storage tanks, and transfer operations, based on emission factors and information provided by refineries. While the Petroleum Refineries NESHAP provided emissions estimates for VOCs and total HAPs at each of the 190 facilities, emission estimates were not available for both of the 112(k) HAPs, only benzene. Because of the lack of speciated HAP emissions data from the NESHAP, it was decided to use the 1992 TRI estimates for 1,3-butadiene. The benzene estimate is from the NESHAP. Emission estimates for petroleum refining (SIC code 2911) provided by the NESHAP and the TRI are the following:^{1,2}

- Benzene: 3685 tons/yr (182 facilities)
- 1,3-Butadiene: 78 tons/yr (78 facilities)

Assumptions on Process and Control Levels

No assumptions were necessary for processes or control levels, as the emissions estimates were provided by the facilities.

Emission Factors

Emission factors were not used to estimate emissions.

Major/Area Assumptions

According to the MACT study, petroleum refineries are likely major sources, based on emissions of VOCs and HAPs. Consequently, all of the petroleum refineries are assumed to be major sources.

Approach and Assumptions for Spatial Apportionment

National emissions were apportioned according to county employment numbers for facilities represented by SIC code 2911.

REFERENCES FOR PETROLEUM REFINING

1. U.S. EPA. July 15, 1994. Petroleum Refinery NESHAP. OAQPS. Research Triangle Park, North Carolina.
2. U.S. EPA. 1993. 1992 Toxic Chemical Release Inventory (SARA 313) Database. Office of Toxic Substances, Washington, DC.

A.27 Oil and Gas Production, Glycol Dehydrators

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national emissions of benzene from glycol dehydrators were obtained from background information from the Oil and Gas Production MACT.¹ It was estimated that 52,900 tons/yr of benzene was emitted from these units.

Assumptions on Process and Control Levels

No assumptions were necessary to obtain MACT emission data.

Emission Factors

No emission factors were needed to estimate emissions.

Major/Area Assumptions

The MACT data indicates there are 27,860 dehydration units considered area sources and 2,140 considered major sources. Of the 52,900 tons/yr of emissions, 42 percent are considered major and 58 percent are considered area emissions.

Approach and Assumptions for Spatial Apportionment

Using the MACT national emission estimates, these national emissions were distributed to individual counties according to the county proportion of national natural gas production.

REFERENCES FOR OIL AND GAS PRODUCTION, GLYCOL DEHYDRATORS

1. U.S. EPA. 1994. Background information for Oil and Gas Production MACT. OAQPS. Research Triangle Park, North Carolina.

Coke Ovens**Pollutant Addressed**

- Benzene

National Emissions

Facility emissions for coke ovens were estimated using two methods. The first method involved modifying a NESHAP study of benzene emissions from coke by-product recovery plants.¹ The second approach used benzene emissions reported in TRI.²

Total annual benzene emissions from coke oven operations were quantified in the USEPA/OAQPS final Benzene NESHAP.¹ The final Benzene NESHAP for coke by-product recovery plants projects that about 97 percent reduction in benzene emissions will be achieved through the final Benzene NESHAP (54 FR 38047, 9/14/89; 40 CFR 61 Subpart L). Using this same methodology and applying a 97 percent emission reduction, results show that adjusted survey emission estimates are similar, but slightly lower, than those reported in the 1992 TRI. Because the Benzene NESHAP estimates were lower than actual emissions reported by TRI and the TRI data compared favorably with the adjusted data, it was recommended that the TRI data for benzene emissions associated with SIC code 3312 (blast furnaces and basic steel products) be used in this inventory.

The national emission estimate for benzene, based on TRI, is 806 tons/yr.

Major/Area Assumptions

The category of coke oven production is assumed to consist entirely of major sources, with each facility typically emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This is a reasonable assumption considering that the majority of the coke production facilities are associated with iron and steel producing plants and that "coke oven emissions" are identified as a specific HAP on the CAAA list of HAPs.

Approach and Assumptions for Spatial Apportionment

The national emissions estimate for coke production sources were divided equally amongst each of the identified facilities within the country. In 1990, there were a total of 29 active coke production facilities within the country. Emissions were classified URBAN-1, URBAN-2, or RURAL depending on the county location of the facility. Emissions were apportioned equally amongst the

facilities since the actual production information for each facility is classified as confidential.

REFERENCES FOR COKE OVENS

1. U.S. EPA. 1984. Benzene Emissions from Coke By-Product Recovery Plants - Background Information for Proposed Standards. OAQPS. Research Triangle Park, North Carolina. EPA-450/3-83-016a.
2. U.S. EPA. 1993. 1992 Toxic Chemical Release Inventory (SARA 313) Database. Office of Toxic Substances, Washington, DC.

A.29 Secondary Lead Smelters

Secondary lead smelting involves the recovery of lead from scrap automobile batteries.

Pollutants Addressed

- Benzene; and
- 1,3-Butadiene.

National Emissions/Activity Levels

The national activity level for secondary lead smelters for the base year 1990 is 948,000 tons lead produced.¹ National emission estimates for benzene and 1,3-butadiene were made using emission factors from the Secondary Lead Smelting NESHAP program.^{2,3}

Assumptions on Process and Control Levels

There are three principal furnace types in operation at secondary lead smelting facilities in the U.S., the blast furnace, the rotary furnace and the reverberatory furnace. Emission control technologies used include baghouses or a baghouse with a scrubber. The emission factors presented below were for uncontrolled emissions from a blast furnace at a secondary lead smelter.

Emission Factors

Table A.29 lists the emission factors for each pollutant that were used to develop the national emissions estimate for secondary lead smelters. Both the benzene and 1,3-butadiene emission factors were developed from the Secondary Lead Smelting NESHAP.²

Table A.29. Secondary Lead Smelters Emission Factors

Pollutant	Emission Factor	Units
Benzene	2.04×10^{-4}	ton/ton lead produced
1,3-Butadiene	5.8×10^{-4} (blast furnaces) 6.5×10^{-5} (rotary furnaces)	ton/ton lead produced

Major/Area Assumptions

The category of secondary lead smelting is assumed to be a 50 percent major/50 percent area source, with 50 percent of all secondary lead smelters emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.⁴

Approach and Assumptions for Spatial Apportionment

Facility specific locations of secondary lead smelters in the U.S. have been compiled under the U.S. EPA Secondary Lead Smelting NESHAP Program. National emission estimates will be assigned to the State level using the ratio of number of facilities in a State to the total number of facilities in the U.S. State level emission estimates will be further disaggregated into the three population subcategories (URBAN-1, URBAN-2, and RURAL) using county specific locations of the 22 secondary lead smelters in the U.S. and the county classifications based on the U.S. Bureau of the Census database developed for this inventory.⁵

REFERENCES FOR SECONDARY LEAD SMELTERS

1. Larrabee, D.A. Lead. 1991. In: U.S. Industrial Outlook 1991. U.S. Department of Commerce, International Trade Administration, Washington, DC.
2. U.S. EPA. 1993. Draft Emission Test Report. HAP Emission Testing on Selected Sources at a Secondary Lead Smelter. East Penn Manufacturing Company. Prepared by Roy F. Weston, Inc. Contract No. 68-D1-0104.
3. U.S. EPA. *Final Background Information Document for Secondary Lead NESHAP*. EPA-450/R-94-024a. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, June 1994.
4. Personal communication between Peter Keller, Radian, and Glenn Rives, Radian. June 16, 1993. Secondary Lead Smelter Total Annual HAP Emissions.
5. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.30 Portland Cement

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for Portland cement kilns in 1992 is about 81 million tons/yr of cement clinker produced by 109 facilities with 212 Portland cement kilns.¹ These activity data are based on all kilns, those burning hazardous waste as well as non-hazardous waste.

Assumptions on Process and Control Levels

A rotary-type kiln is used to manufacture Portland cement. Coal or petroleum coke are typical fuels used to sustain combustion in the kiln. However, for cost savings, it is estimated that 34 of the existing 212 cement kilns burn hazardous liquid and solid waste as supplemental fuels. The most common emission control technologies used at cement kilns are controls for dust and PM, including fabric filters and ESPs.

Emission Factors

Table A.30 presents the emission factor that was used to develop the national emissions estimate for Portland cement kilns. The emission factor was derived from a 1994 Office of Solid Waste report.² The factor reflects testing both with a combination of conventional fuel and hazardous waste feed and hazardous waste feed alone.

Major/Area Assumptions

The number of Portland cement facilities in the United States that are major sources is not readily available. However, from recent MACT analysis, it is estimated that between 47 and 86 percent of Portland cement facilities are area sources (would not meet the 10/25 tons/yr threshold).³

Approach and Assumptions for Spatial Apportionment

A list of all the Portland cement facilities in the U.S. is available through recent MACT work. Because no facility-specific production data were

available, national emissions were divided equally amongst these individual facilities and allocated to the counties in which the facilities are located.³

Table A.30. Portland Cement Kiln Emission Factor

Pollutant	Emission Factor	Units
Benzene	2.52×10^{-3}	lb/ton clinker produced

REFERENCES FOR PORTLAND CEMENT

1. U.S. EPA. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, and Occurrence and Background Exposures. External Review Draft. Office of Health and Environmental Assessment, Washington, D.C. EPA-600/6-88-55b. June 1994.
2. U.S. EPA. May 17, 1994. Technical Support for Revision of the Hazardous Waste Combustion Regulations for Cement Kilns and Other Thermal Treatment Devices. Second draft. Office of Solid Waste, Washington, DC.
3. Memorandum to Tom Lahre, EPA/OAQPS, from Terry Pierson, Research Triangle Institute. "Summary of Portland Cement MACT Data." April 25, 1994.

A.31 Iron and Steel Foundries

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

The national activity level for iron and steel foundries for the base year 1990 is 10,199,820 tons of iron/steel product produced.¹ The national activity level estimate for ferrous foundries includes 9.15×10^6 tons of iron castings and 1.10×10^6 tons of steel castings produced by approximately 1100 foundries nationally in 1990.¹ Emission factors were used to estimate emissions associated with the national activity data.

Assumptions on Process and Control Levels

The emission factor used to estimate emissions from iron and steel foundries was derived from a 1990 test report for an iron foundry with a cupola furnace controlled with a flare and water scrubber.²

Emission Factors

Table A.31 lists the emission factor for benzene that was used to develop the national emissions estimate for iron and steel foundries. The benzene emission factor was derived from a 1990 test report.²

Table A.31. Iron and Steel Foundry Emission Factor

Pollutant	Emission Factor	Units
Benzene	2.94×10^{-7}	ton/ton iron produced

Major/Area Assumptions

Iron and steel foundries are assumed to be major sources, with all facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Approach and Assumptions for Spatial Apportionment

National emissions will be equally divided among all facilities listed under SIC code 332 (iron and steel foundries) to estimate county emissions. Emission estimates will be further disaggregated into the three population subcategories (URBAN-1, URBAN-2, and RURAL) using the county classification from the 1990 U.S. Bureau of Census database.³

REFERENCES FOR IRON AND STEEL FOUNDRIES

1. Iron and Steel, In: Mineral Commodity Summaries. 1991. U.S. Department of The Interior, Bureau of Mines. Washington, DC.
2. Environmental Technology and Engineering Corporation. September 5-6, 1990. Report to Waupaca Foundry, Inc., Waupaca, Wisconsin, for Plant/Stack Emissions. Elm Grove, Wisconsin.
3. U.S. Department of Commerce. 1990. Census Data and County Business Statistics, U.S. Bureau of the Census, Washington, DC.

A.32 Chemical and Allied Products (SIC code 28)

Manufacturers and users of chemicals are included in the chemicals and allied products source category, which includes several types of facilities classified under SIC code 28. The chemicals and allied products source category includes the following subcategories:

• Alkalies and chlorine	2812
• Industrial gases	2813
• Industrial inorganic chemicals, nec	2819
• Plastics materials and resins	2821
• Synthetic rubber	2822
• Pharmaceutical preparations	2834
• Medicinals and botanicals	2833
• Gum and wood chemicals	2861
• Cyclic crudes and intermediates	2865
• Industrial organic chemicals, nec	2869
• Nitrogenous fertilizers, nec	2873
• Agricultural chemicals, nec	2879
• Chemical preparations, nec	2899

Based on chemical feedstocks used in the production process, these subcategories are emission sources for the pollutants covered in this survey. The production of acetal, amino, and phenolic resins produces formaldehyde emissions. The chemical, 1,3-butadiene, is a constituent of plastics materials and synthetic rubber feedstock. Benzene is a common byproduct in the manufacture of petroleum products.

Pollutants Addressed

- Benzene;
- 1,3-Butadiene; and
- Formaldehyde

National Activity Level/Emission Estimates

An effort was made to obtain emissions data for chemicals and allied products from existing inventories, particularly the Polymers and Resins I NESHAP. However, contact with individuals (including the EPA Polymers and Resins work assignment manager) familiar with the NESHAP data indicated the data were still undergoing revision and the current data could not be reliably cited. Therefore, it was decided to use the TRI emissions estimates for all of the pollutants associated with chemicals and allied products manufacturers and users.¹

The subcategories (represented by 4-digit SIC codes) associated with a specific pollutant are listed in Table A.32. The TRI emissions for these subcategories were summed and this summation is represented by the 2-digit SIC code 28.

Assumptions on Process and Control Levels

No assumptions were necessary for processes or control levels, as the emissions estimates were provided by the facilities.

Emission Factors

Emission factors were not used to estimate emissions.

**Table A.32. Chemicals and Allied Products Subcategories
and Representative SIC Codes**

Benzene	
2812	Alkalies and chlorine
2819	Industrial inorganic chemicals, nec
2821	Plastics materials and resins
2822	Synthetic rubber
2865	Cyclic crudes and intermediates
2869	Industrial organic chemicals, nec
2879	Agricultural chemicals, nec
1,3-Butadiene	
2812	Alkalies and chlorine
2819	Industrial inorganic chemicals, nec
2821	Plastics materials and resins
2822	Synthetic rubber
2869	Industrial organic chemicals, nec
2879	Agricultural chemicals, nec
2899	Chemical preparations, nec
Formaldehyde	
2812	Alkalies and chlorine
2813	Industrial gases
2819	Industrial inorganic chemicals, nec
2821	Plastics materials and resins
2822	Synthetic rubber
2861	Gum and wood chemicals
2869	Industrial organic chemicals, nec
2873	Nitrogenous fertilizers
2879	Agricultural chemicals, nec
2899	Chemical preparations, nec

Major/Area Assumptions

The following major/area percent allocations for the 112(k) pollutants emissions were based on a report prepared by Pechan and Associates in 1992:²

- Benzene: 98/2
- 1,3-Butadiene: 98/2
- Formaldehyde: 91/9

Approach and Assumptions for Spatial Apportionment

The emissions were apportioned by county employment, based on the 4-digit SIC codes found in Table A.32.

REFERENCES FOR CHEMICALS AND ALLIED PRODUCTS

1. U.S. EPA. 1993. 1992 Toxic Chemical Release Inventory (SARA 313) Database. Office of Toxic Substances, Washington, D.C.
2. E.H. Pechan & Associates, Incorporated. 1992. Calculating Emission-Based Hazard Indices for Hazardous Air Pollutants, prepared for U.S. EPA, Research Triangle Park, North Carolina.

A.33 Wood Products (SIC Codes 24 and 25)

Wood products include facilities producing reconstituted wood products (SIC code 2493), softwood veneer and plywood (SIC code 2436), hardwood veneer and plywood (SIC code 2435), wood TV and radio cabinets (SIC code 2517), wood office furniture (SIC code 2521), wood kitchen cabinets (SIC code 2434), wood household furniture (SIC code 2511), other structural wood members (SIC code 2439), and other wood products (SIC code 2499). Production of plywood wafer board, particle board, and oriented strand board is a large source of formaldehyde emissions because formaldehyde-based resins/adhesives are used to bind wooden parts together. The largest formaldehyde-emitting units within a plant are presses and dryers.

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

An effort was made to obtain emissions data from other inventory reports.^{1,2} However, the reports identified pertained to only plywood production and their applicability to all similar sources was somewhat questionable. Because of the uncertainty about the numbers from the reports, it was decided to use the TRI data to estimate emissions from wood product production.² According to 1992 TRI, total emissions for formaldehyde for wood products production were 1,504 tons/yr which shows close agreement with the estimates from the other inventory reports.

The subcategories associated with 4-digit SIC codes for specific pollutants are listed in Table A.33. Because there were so many diverse but applicable 4-digit SIC level sources, the TRI emissions for these subcategories were summed and classified under SIC codes 24 and 25 to give total national emissions estimates for wood product production. The emissions associated with those specific subcategories can be found in Section 4.0.

Assumptions on Process and Control Levels

No assumptions were necessary for processes or control levels, as the emissions estimates were provided by the facilities.

**Table A.33. Wood Products Subcategories and
Representative SIC Codes**

2434	Wood kitchen cabinets
2435	Hardwood veneer and plywood
2436	Softwood veneer and plywood
2439	Structural wood members, nec
2493	Reconstituted wood products
2499	Wood products, nec
2511	Wood household furniture
2517	Wood TV and radio cabinets

Emission Factors

Emission factors were not used to estimate emissions.

Major/Area Assumptions

All of the facilities are assumed to be major sources, based on annual average formaldehyde emissions of 85 tons per year.

Approach and Assumptions for Spatial Apportionment

National emissions were apportioned to the State and county level using county employment under SIC codes 24 and 25.

REFERENCES FOR WOOD PRODUCTS

1. Air Permit Review for Weyerhaeuser Company, Moncure, NC. May 1993.
2. Memorandum from Shannon Vogel, NC Division of Environmental Management, to Vic Copelan, Georgia Pacific Corporation. October 26, 1992. Testing of the Oriented Strand Board Process.
3. U.S. EPA. 1993. 1992 Toxic Chemical Release Inventory (SARA 313) Database. Office of Toxic Substances, Washington, DC.

A.34 Publicly Owned Treatment Works (POTWs)

Air emissions from POTWs occur through contact of wastewater with air. Most emissions come from air strippers, trickling filters and rotating biological contactors that are designed to maximize contact with air to increase the dissolved oxygen content of the waste stream. Activated sludge and oxidation ditches also emit air pollutants when agitated or when oxygen or air is bubbled through the wastewater and into the atmosphere.

Pollutants Addressed

- Benzene; and
- Formaldehyde.

National Activity Level/Emissions Estimates

Together, primary, secondary and advance wastewater systems treat 89 percent of municipal wastewater flow. Using the EPA Office of Water's 1988 Needs Survey¹ in conjunction with emission factors from a California Air Resources Board (CARB) study performed by James Montgomery and Company,² national emission estimates were calculated.

Municipal wastewater flows were documented in the Needs Survey. The 1988 Needs report was preferred because the data quality is supposedly better than the 1990 and 1992 reports. The Needs Survey provides number of facilities and wastewater flow for each State in terms of millions of gallons per day (MGD). Annual flow was estimated by multiplying MGD by 365 days. State flow data are summarized in Table A.34-1.

The Needs Survey also documents that 12 percent of the national wastewater flow is treated by primary and advance primary systems, 55 percent by secondary wastewater treatment facilities, and 22 percent goes to advanced wastewater systems. This information was used to apportion state wastewater flows into general treatment categories.

Assumptions on Process and Control Levels

To estimate emissions using the national flow data using CARB unit process-specific emission factors, assumptions had to be made regarding what

Table A.34-1. Municipal Waste Flow and Estimated Emissions ^a

State	Facilities	Total Flow (mgd)	Emission (Tons/Year)	
			Benzene	Formaldehyde
Alabama	246	356	0.69	0.50
Alaska	45	52	0.10	0.07
Arizona	116	266	0.51	0.37
Arkansas	295	240	0.46	0.33
California	588	2,889	5.59	4.02
Colorado	280	394	0.76	0.55
Connecticut	102	371	0.72	0.52
Delaware	16	88	0.17	0.12
DC	1	310	0.60	0.43
Florida	264	1,006	1.95	1.40
Georgia	391	571	1.11	0.79
Hawaii	30	128	0.25	0.18
Idaho	156	90	0.17	0.13
Illinois	727	2,148	4.16	2.99
Indiana	360	722	1.40	1.01
Iowa	687	311	0.60	0.43
Kansas	569	234	0.45	0.33
Kentucky	227	264	0.51	0.37
Louisiana	328	399	0.77	0.56
Maine	115	113	0.22	0.16
Maryland	163	378	0.73	0.53
Massachusetts	116	886	1.71	1.23

Table A.34-1. (Continued)

State	Facilities	Total Flow (mgd)	Emission (Tons/Year)	
			Benzene	Formaldehyde
Michigan	379	1,385	2.68	1.93
Minnesota	511	448	0.87	0.62
Mississippi	303	192	0.37	0.27
Missouri	608	651	1.26	0.91
Montana	166	63	0.12	0.09
Nebraska	449	175	0.34	0.24
Nevada	51	169	0.33	0.24
New Hampshire	84	82	0.16	0.11
New Jersey	201	975	1.89	1.36
New Mexico	103	118	0.23	0.16
New York	483	2,446	4.73	3.41
North Carolina	415	478	0.93	0.67
North Dakota	297	45	0.09	0.06
Ohio	691	1,850	3.58	2.58
Oklahoma	499	246	0.48	0.34
Oregon	204	310	0.60	0.43
Pennsylvania	690	1,489	2.88	2.07
Rhode Island	20	143	0.28	0.20
South Carolina	203	275	0.53	0.38
South Dakota	274	58	0.11	0.08
Tennessee	240	488	0.94	0.68
Texas	1,291	2,062	3.99	2.87
Utah	96	236	0.46	0.33

Table A.34-1. (Continued)

State	Facilities	Total Flow (mgd)	Emission (Tons/Year)	
			Benzene	Formaldehyde
Vermont	89	43	0.08	0.06
Virginia	244	490	0.95	0.68
Washington	257	550	1.06	0.77
West Virginia	177	180	0.35	0.25
Wisconsin	584	630	1.22	0.88
Wyoming	103	49	0.09	0.07
Total	15,534	28,542	55	40

^aSource: USEPA\OW (1988)

unit processes are in a typical primary, secondary and advanced treatment facility. These assumptions are noted in Table A.34-2.

Emission Factors

The CARB study tested 19 different wastewater treatment unit processes. Each of these processes were tested at three different facilities yielding facility-specific emission factors for each of the unit processes. Because these facility-specific emission factors varied by one or more orders of magnitude, the geometric average for this test data was used to characterize emissions from each of the unit processes.

These averaged emission factors were assigned to each unit process as presented in Table A.34-3. Emission factors that characterize the three facility types (primary, secondary, and advanced) were developed by summing the appropriate unit emission factors as defined in Table A.34-3.

Not every treatment facility type uses the same unit processes. For example, some secondary treatment facilities use only trickling filters, some use activated sludge and some use both. Unit process emission factors were weighted relative to the flow information in the Needs Survey. For instance, for secondary wastewater treatment, 21 percent of the national treatment flow goes to trickling filters while 79 percent goes to activated sludge, such that these unit processes emission factors were multiplied by 0.21 and 0.79, respectively, in the summation of emission factors.

The emission factors that characterize primary, secondary, and advance facility types are applied to the apportioned State wastewater flows to estimate emissions. These emission estimates are presented in Table A.34-1.

Major/Area Assumptions

POTWs are unlikely to be large enough sources of HAPs to be considered major sources. This remains true even if co-location of sludge incinerators are included in total emission estimates. Total HAP emissions from POTWs were summed and divided by the total number of facilities to calculate the average HAP emission for a facility. The average HAP emission

Table A.34-2. Typical Processes for Municipal Wastewater Treatment Systems^a

Process	Facility Census Data		Facility Treatment Types		
	Number of Facilities	Flow	Primary	Secondary	Advanced
Preliminary Treatment	26,370	107,391	✓	✓	✓
Primary Sedimentation	5,945	37,718	✓	✓	✓
Trickling Filters	2,761	7,833		✓	
Activated Sludge	6,655	29,886		✓	✓
Filtration	2,112	8,044		✓	✓
Post Aeration	1,116	4,394			✓
Dechlorination	348	2,030			✓
Disinfection	8,936	29,356	✓	✓	✓
Thickening	1,324	18,928		✓	✓
Dewatering	1,802	21,678		✓	✓
Air Drying	6,037	11,492	✓	✓	

^a USEPA/OW (1988)

for a facility was approximately 0.5 tons per year. This suggests that the average facility is an area source. Next, a typically large facility was considered with sludge incineration co-located with the POTW. The combined emissions were approximately 2 tons, well below the major source cutoff. Therefore, all POTWs are assumed to be area sources.

Approach and Assumptions for Spatial Apportionment

These estimated emissions were allocated to the urban population clusters of each State. In making this apportionment, the assumption is made that only urban populations are served by POTWs. Though this assumption seems reasonable, it was checked by comparing the percent of each State's population that is urban as reported in the U.S. Census and the percent of each State's population that is served by a POTW as reported in the Needs Survey. States that have large urban clusters should have a higher percentage of the population being served by POTWs than States with large rural population. The percent served was subtracted from the percent urban; this value was weighted

Table A.34-3. POTW Emission Factors^a

Process	Benzene (lbs/MG)	Formaldehyde (lbs/MG)
Head works	0.006500	0.000000
Primary Sedimentation	0.000535	0.000192
Trickling Filters	0.001600	0.000540
Activated Sludge	0.000442	0.000027
Filtration	0.000004	0.000000
Secondary Clarification	0.000140	0.000001
Dechlorination	0.000000	0.000000
Chlorination	0.000139	0.000001
Gravity Thickening	0.000105	0.000050
Dewatering	0.003800	0.009127
Air Drying	0.002800	0.001200
Primary Treatment ^b	0.000006	0.000001
Secondary Treatment ^b	0.000034	0.000027
Advanced Treatment ^b	0.000013	0.000010

^aCARB (1992)

^bDerived emissions factors in tons/MG and adjusted for percent of flow.

by multiplying it with the State's population and normalized by dividing the value by the national population. These data are summarized in Table A.34-4. This table suggests that the urban population appears to be correlated to the percentage of the State's population being served by POTWs. The use of this assumption will, in some cases, lead to a slight over-estimation of urban emissions in this inventory, particularly for California, Florida and New York.

REFERENCES FOR POTWs

1. U.S. EPA. 1988. Office of Water, Draft, 1988 Needs Survey Data. Washington, D.C. (never published).
2. James M. Montgomery Consulting Engineers, Incorporated. December 10, 1990. Joint Powers Agencies for Pooled Emission Estimation Program (PEEP), Final Report for Publicly Owned Treatment Works. Pasadena, California.

Table A.34-4. Comparison of State Urban Population with Wastewater Services^a

State	Population			Percent Urban	Needs % Served	Weighted Error
	Total	Urban	Rural			
Alabama	4,040,587	2,439,549	1,601,038	60	56	0.07
Alaska	550,043	371,235	178,808	67	61	0.01
Arizona	3,665,228	3,206,973	458,255	87	83	0.07
Arkansas	2,350,725	1,258,021	1,092,704	54	60	-0.06
California	29,760,021	27,571,321	2,188,700	93	85	0.91
Colorado	3,294,394	2,715,517	578,877	82	93	-0.14
Connecticut	3,287,116	2,601,548	685,568	79	62	0.23
Delaware	666,168	486,501	179,667	73	72	0.00
DC	606,900	606,900		100	208	-0.26
Florida	12,937,926	10,967,328	1,970,598	85	62	1.18
Georgia	6,478,216	4,097,339	2,380,877	63	59	0.11
Hawaii	1,108,229	986,171	122,058	89	68	0.09
Idaho	1,006,749	578,214	428,535	57	99	-0.17
Illinois	11,450,602	9,668,552	1,782,050	84	87	-0.12
Indiana	5,544,159	3,598,099	1,946,060	65	64	0.02
Iowa	2,776,755	1,683,065	1,093,690	61	73	-0.14
Kansas	2,477,574	1,712,564	765,010	69	81	-0.12
Kentucky	3,685,296	1,910,325	1,774,971	52	48	0.06
Louisiana	4,219,973	2,871,759	1,348,214	68	72	-0.07
Maine	1,227,928	547,824	680,104	45	48	-0.02
Maryland	4,781,468	3,888,429	893,039	81	58	0.45
Massachusetts	6,016,425	5,069,603	946,822	84	70	0.34
Michigan	9,295,297	6,555,842	2,739,455	71	76	-0.20
Minnesota	4,375,099	3,056,474	1,318,625	70	74	-0.07
Mississippi	2,573,216	1,210,729	1,362,487	47	58	-0.11
Montana	799,065	419,826	379,239	53	62	-0.03
Nebraska	1,578,385	1,043,984	534,401	66	80	-0.09
Nevada	1,201,833	1,061,444	140,389	88	91	-0.01

Table A.34-4. (Continued)

State	Population			Percent Urban	Needs % Served	Weighted Error
	Total	Urban	Rural			
New Hampshire	1,109,252	565,670	543,582	51	49	0.01
New Jersey	7,730,188	6,910,220	819,968	89	82	0.23
New Mexico	1,515,069	1,105,651	409,418	73	68	0.03
New York	17,990,455	15,164,047	2,826,408	84	73	0.82
North Carolina	6,628,637	3,337,778	3,290,859	50	43	0.20
North Dakota	638,800	340,339	298,461	53	68	-0.04
Ohio	10,847,115	8,039,409	2,807,706	74	73	0.05
Oklahoma	3,145,585	2,130,139	1,015,446	68	76	-0.10
Oregon	2,842,321	2,003,271	839,050	70	70	0.01
Pennsylvania	11,881,643	8,188,295	3,693,348	69	78	-0.43
Rhode Island	1,003,464	863,381	140,083	86	67	0.08
South Carolina	3,486,703	1,905,378	1,581,325	55	50	0.07
South Dakota	696,004	347,903	348,101	50	67	-0.05
Tennessee	4,877,185	2,969,948	1,907,237	61	50	0.21
Texas	16,986,510	13,634,517	3,351,993	80	84	-0.25
Utah	1,722,850	1,499,091	223,769	87	77	0.07
Vermont	562,758	181,149	381,609	32	52	-0.04
Virginia	6,187,358	4,293,443	1,893,915	69	65	0.11
Washington	4,866,692	3,717,948	1,148,744	76	62	0.28
West Virginia	1,793,477	648,184	1,145,293	36	55	-0.14
Wisconsin	4,891,769	3,211,956	1,679,813	66	72	-0.12
Wyoming	453,588	294,635	158,953	65	72	-0.01
Total	248,729,873	187,053,487	61,676,386			

^a USEPA\OW (1988)

A.35 Landfills

Pollutant Addressed

- Benzene

National Activity Level/Emission Estimates

National emissions of the above pollutants for Municipal Solid Waste (MSW) landfills were estimated using the guidance provided in EPA's Compilation of Air Pollutant Emission Factors (AP-42) (based on the EPA's Landfill Air Emissions Estimation model) and a national (i.e., 11.5×10^{12} g/yr) estimate of methane (CH_4) generated from MSW landfills in the United States obtained from a technical document written in support of the proposed NSPS for landfills.^{1,2} Using the AP-42 guidance, the national volumetric flow rate of CH_4 (m^3/yr) was calculated based on the national mass flow rate of CH_4 (kg/yr), assuming that the average landfill gas temperature is 25°C . Next the national volumetric flow rate of landfill gas (m^3/yr) was calculated, based on the national volumetric flow rate of CH_4 (m^3/yr), assuming the landfill gas consists of 50 percent CH_4 and 50 percent CO_2 by volume.

Using equations provided in the AP-42 document to determine benzene emissions, the national volumetric emission rate of benzene (m^3/yr) was then calculated based on the national volumetric flow rate of landfill gas (m^3/yr), assuming the benzene concentration in landfill gas is 2.25 ppmv (i.e., the benzene emission concentration provided in the AP-42 document for a MSW landfill with an "unknown" status with regard to co-disposal with hazardous waste). Finally, the national mass emission rate of benzene (kg/yr) was calculated, based on the national volumetric emission rate of benzene (m^3/yr), assuming the landfill gas temperature is 25°C . The following is an example calculation for benzene emissions from a MSW landfill:

Calculate volumetric flow rate of CH₄:

$$\begin{aligned}
 \text{Volumetric flow rate of CH}_4 \text{ (m}^3\text{/yr)} &= \frac{\text{mass flow rate of CH}_4 \text{ (kg/yr)}}{\text{molecular weight of CH}_4} \\
 &= \frac{\left(8.205 \times 10^{-5} \frac{\text{m}^3 \times \text{atm}}{\text{mol} \times ^\circ\text{K}} \right) (1000 \text{ g}) (273 + 25^\circ\text{C})}{16} \\
 &= 1.76 \times 10^{10} \text{ m}^3\text{/yr}
 \end{aligned}$$

Calculate volumetric flow rate of landfill gas (LFG):

$$\begin{aligned}
 \text{Volumetric flow rate of LFG (m}^3\text{/yr)} &= 2 \times \text{volumetric flow rate of CH}_4 \text{ (m}^3\text{/yr)} \\
 &= 2 \times (1.76 \times 10^{10} \text{ m}^3\text{/yr)} \\
 &= 3.52 \times 10^{10} \text{ m}^3\text{/yr}
 \end{aligned}$$

Calculate volumetric emission rate of benzene:

$$\begin{aligned}
 \text{Volumetric emission rate of benzene (m}^3\text{/yr)} &= \text{volumetric flow rate of LFG (m}^3\text{/yr)} \times \frac{\text{concentration of benzene in LFG (ppmv)}}{1 \times 10^6} \\
 &= 3.52 \times 10^{10} \text{ m}^3\text{/yr} \times \frac{2.25 \text{ ppmv}}{1 \times 10^6} \\
 &= 79,200 \text{ m}^3\text{/yr}
 \end{aligned}$$

Calculate mass emission rate of benzene:

$$\begin{aligned}
 \text{Mass emission rate of benzene (kg/yr)} &= \text{volumetric emission rate of benzene (m}^3\text{/yr)} \times \left[\frac{\text{molecular weight of benzene}}{\left(8.205 \times 10^{-5} \frac{\text{m}^3 \times \text{atm}}{\text{mol} \times ^\circ\text{K}} \right) (1000 \text{ g}) (273 + 25^\circ\text{C})} \right] \\
 &= 79,200 \text{ m}^3\text{/yr} \times \left[\frac{78}{\left(8.205 \times 10^{-5} \frac{\text{m}^3 \times \text{atm}}{\text{mol} \times ^\circ\text{K}} \right) (1000 \text{ g}) (273 + 25^\circ\text{C})} \right] \\
 &= 252,653 \text{ kg/yr}
 \end{aligned}$$

$$\begin{aligned}
 \text{National emissions estimate} &= 252,653 \text{ kg/yr} \times 1.1 \times 10^{-3} \text{ ton/yr} \\
 &= 278 \text{ ton/yr}
 \end{aligned}$$

Assumptions on Process and Control Levels

Landfills are generally considered uncontrolled sources.

Emission Factors

No emission factors were used in estimating national landfill emissions.

Major/Area Assumptions

Landfills are considered area sources.

Approach and Assumptions for Spatial Apportionment

National emissions were assigned to State emissions based on State proportion of URBAN 1, URBAN2, and RURAL population.

REFERENCES FOR LANDFILLS

1. U.S. EPA. October 1992. Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources. AP-42. Section 2.4. OAQPS. Research Triangle Park, NC.
2. Memorandum from S. Fields, Radian Corporation, to D. Doll, U.S. EPA. April 6, 1993. 1992 and 2000 Actual Methane Emission Estimates.

A.36 Consumer/Commercial Products Solvent Use

Consumer products are used by individuals in a household setting (i.e., around the home, workshop, garden, and garage). These products include, but are not limited to, household cleaners, personal care products, household pesticides, automotive aftermarket products, household adhesives, and architectural coatings. Commercial products are used in a variety of commercial, institutional, or industrial settings and include products similar in nature to consumer products. Examples include cleaning supplies used by hospitals and schools, pesticides applied by pest control operators, coatings used by painting contractors, hair sprays used in salons, products used in auto repair shops, cutback asphalt paving materials, industrial mold release agents, and solvents used to clean equipment and tools (does not include solvent used in solvent cleaning machines).

Pollutant Addressed

- Formaldehyde

National Activity Level/Emission Estimates

The 1990 national emissions estimates from consumer and commercial products are based on the results of a survey that the EPA distributed to producers of consumer and commercial products under the authority of section 114 of the Act.¹ The primary purpose of the survey was to obtain information on the amount of VOCs (speciated HAPs) contained in consumer and commercial products. If a respondent reported on a product line that contained greater than 5 percent weight VOC, the weight percent of each VOC compound was reported. The volume of sales for each product line was also reported. This survey was sent to approximately 5000 respondents. Response to this survey was reportedly representative of 90 percent of consumer and commercial product sales nationally, except for the spray paint category, which represented 100 percent of product sales nationally.²

The following consumer and commercial product categories reported product lines that contained HAPs:

- Hard surface cleaners;
- Fabric, carpet and upholstery products;
- Air fresheners;

- Miscellaneous household products;
- Detailing products;
- Maintenance and repair products;
- Adhesives;
- Sealants;
- Antimicrobial agents;
- Aerosol spray paints and coatings;
- Coatings related products; and
- Arts and crafts supplies.

From the survey, a table of speciated HAP emissions per consumer and commercial product category was developed. All subcategory HAP emissions, except for those reported for aerosol spray paints and coatings, were adjusted to represent a 100 percent response rate. (Aerosol spray paints and coatings survey response was reportedly 100 percent.)

Assumptions on Process and Control Levels

The HAP emissions from consumer and commercial products considered in this inventory are fugitive emissions. Hazardous air pollutants contained in consumer and commercial products are assumed to be ultimately emitted during use. Therefore, measures to control HAP emissions from consumer and commercial products include reducing the HAP content of a product or use of the product. Note that not all consumer and commercial product lines are accounted for in this HAP emissions estimate, including those product lines that have less than 5 percent by weight VOC. Also note that equating HAP emissions with HAP content of consumer and commercial products does not account for the fate of HAPs that may enter the municipal solid waste stream or are introduced into wastewater treatment systems.

Emission Factors

An emission factor was not necessary to estimate national emissions.

Major/Area Assumptions

The consumer and commercial product category is assumed to be an area source, however, there is a potential that some major HAP sources may employ the use of these HAP-containing products on a small scale.

Approach and Assumptions for Spatial Apportionment

National emissions were allocated to the State and county level using each State's population. This allocation of emissions assumes that use and emissions are driven by consumer demand and that demand is ubiquitous nationally.

REFERENCES FOR CONSUMER/COMMERCIAL PRODUCTS SOLVENT USE

1. U.S. EPA. December 1, 1993. Consumer Products Survey. Draft RVOC Species Database. OAQPS. Research Triangle Park, NC.